NASA Contractor Report 166091

FUEL CONTAINMENT AND DAMAGE TOLERANCE IN LARGE COMPOSITE PRIMARY AIRCRAFT STRUCTURES PHASE I - TESTING

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FATIGUE AND FRACTURE MECHANICS LABORATORY
RYE CANYON RESEARCH LABORATORY
BURBANK, CALIFORNIA

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SECTION 1
INTRODUCTION

This report summarizes the test results for work on Phase I of the NASA Key Technology Program "Fuel Containment and Damage Tolerance in Large Composite Primary Aircraft Structures", Contract No. NAS1-16856. The work was broken into three areas: 1) Material Screening Tests; 2) Surface Preparation and Fuel Containment Tests; and 3) Design Data Tests. These are reported in Section 2, 3, and 4 respectively. Supporting detailed data are contained in the Appendices.

Laminates were fabricated by Manufacturing Research, and inspected by Quality Assurance for acceptance or rejection, limited summary data from these operations are included in the Appendices.

SECTION 2
MATERIAL SCREENING TESTS

2.1 LAMINATE DATA

Laminates for the Material Screening tests were fabricated by Manufacturing Research, inspected by Q.A., and supplied to Rye Canyon ready for machining into test specimens. Three laminates were submitted for various tests: AS4/2220-1; AS4/3502; and Celion/982. The laminate data including layup, size, resin content, and processing data are tabulated in Appendix A-1. Process control data for the laminates used for tensile and compressive tests (panels 12 and 13) are listed in Table 2.1.

2.2 TRIAL IMPACT TESTS

Trial impact tests were conducted on AS4/3502, AS4/2220, and Celion/982 quasi-isotropic laminates. The trial impact panels were 7-in. wide by 25-in. long. For the 3502 and 2220 materials, two thicknesses were investigated, 48 plies and 96 plies. Most panels, however, were 48 plies since all compression testing was done on that thickness.

A special impactor was built for this test series consisting of a 7 foot long aluminum tube with a 3 1/4 inch I.D. This tube was mounted on an existing impactor frame used for lower energy testing. A 3-inch diameter steel bar 5-3/4 inches long was used for the tup. A 1/2-inch diameter 4340 steel (220 ksi) hemispheric head tip was mounted on the tup with a ring eyelet on the opposite end for attachment of a nylon cord. This cord was passed through the tube to a pulley on the top of the assembly as shown in Figure 2-1. With the cord the tup could be pulled up inside the tube to any height desired. Holes were drilled into the aluminum tube at heights

TABLE 2.1 - PROCESS CONTROL DATA FOR MATERIAL SCREENING TEST LAMINATES

	AS4/2220 Panel#12	Celion/982 Panel #13
Orientation (3) $(45, 90, 135, 0)_{6S}$	Pass	Pass
C-Scan	Pass	Pass
Interlaminar (1) Tension (psi)	2783	2033
Resin Content (1)	34.32	36.33
Specific Gravity (1)	1.55	1.52
Thickness (2)	.2637	.3054

(1) Average of 3 specimens

(2) Average of 12 measurements

(3) 2^0 grind-down

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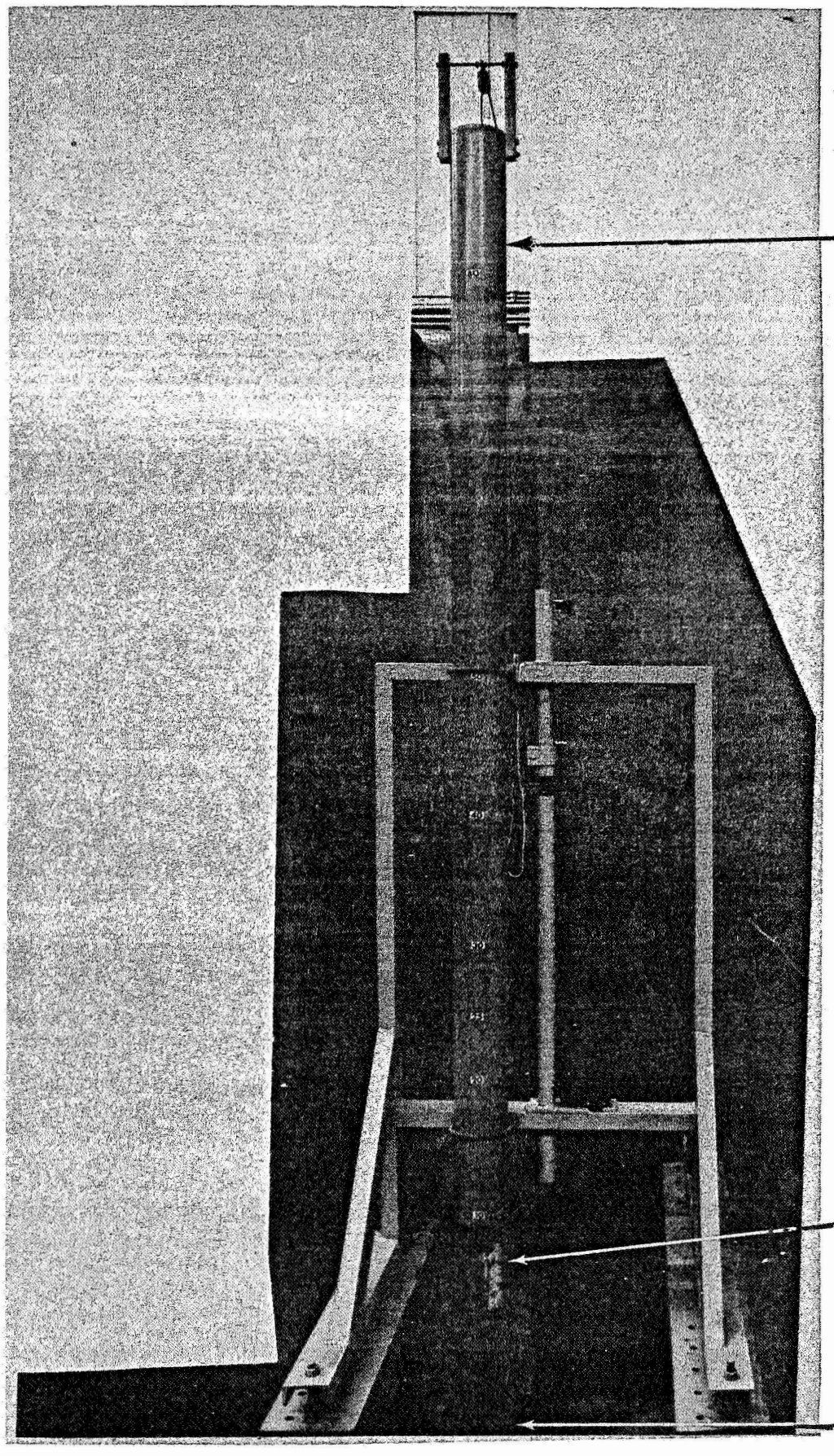


Figure 2-1: Impactor Assembly

corresponding to desired energy levels; eg., 20, 25, 30, etc. ft.-lbs. The maximum design energy required was 80 ft.-lbs. For testing the tup was raised to the desired energy level above the drilled hole, a 1/4 inch diameter steel pin was inserted part way through the tube I.D. and the tup lowered until it rested on the pin. The cord was then released. Pulling the pin released the tup for a free fall. An operator was positioned to catch the tup immediately after impact to prevent a restrike.

The impact panels were supported on a steel base plate with an opening of 5-inches by 5-inches. The panels were held in place with a steel picture frame which was bolted in the corners to 20 ft. lbs. torque. A typical setup is shown in detail in Figure 2-2.

After impact the panels were visually inspected and damage recorded. Photographs were made of both sides of the panels as shown in Figures 2-3 and 2-4. They were then ultrasonically inspected to determine the extent of internal delamination. C-Scan length, width, and area were tabulated for each impact. These data are tabulated for Celion/982 in Table 2.2, for AS4/2220-1 in Table 2.3, and for AS4/3502 in Table 2.4. As shown in these tables for 48 ply laminates, greater damage in the form of a delamination occurred on the back surface of the impact than on the front surface where damage was normally in the form of a small dent; whereas on the 96 ply laminates visible damage was confined primarily to the front surface and no damage on the back surface until penetration. In the photographs the front surface dent is visible primarily due to the chalk dust applied to the tup tip which enhances the dent. Without this dust those impacts listed as slight and medium dents would not be easily spotted. They are characterized qualitatively in these tables by feel, not visual appearance. Only those listed as large dents showed visible evidence of front surface fiber breakage. The visible threshold for back surface damage is between 20 and 30 ft.-lbs. A number of trial impact panels were subsequently used for fuel seepage tests, reported in Section 4.8. Those remaining were used to establish quantative values for impact depth versus impact energy. Tables

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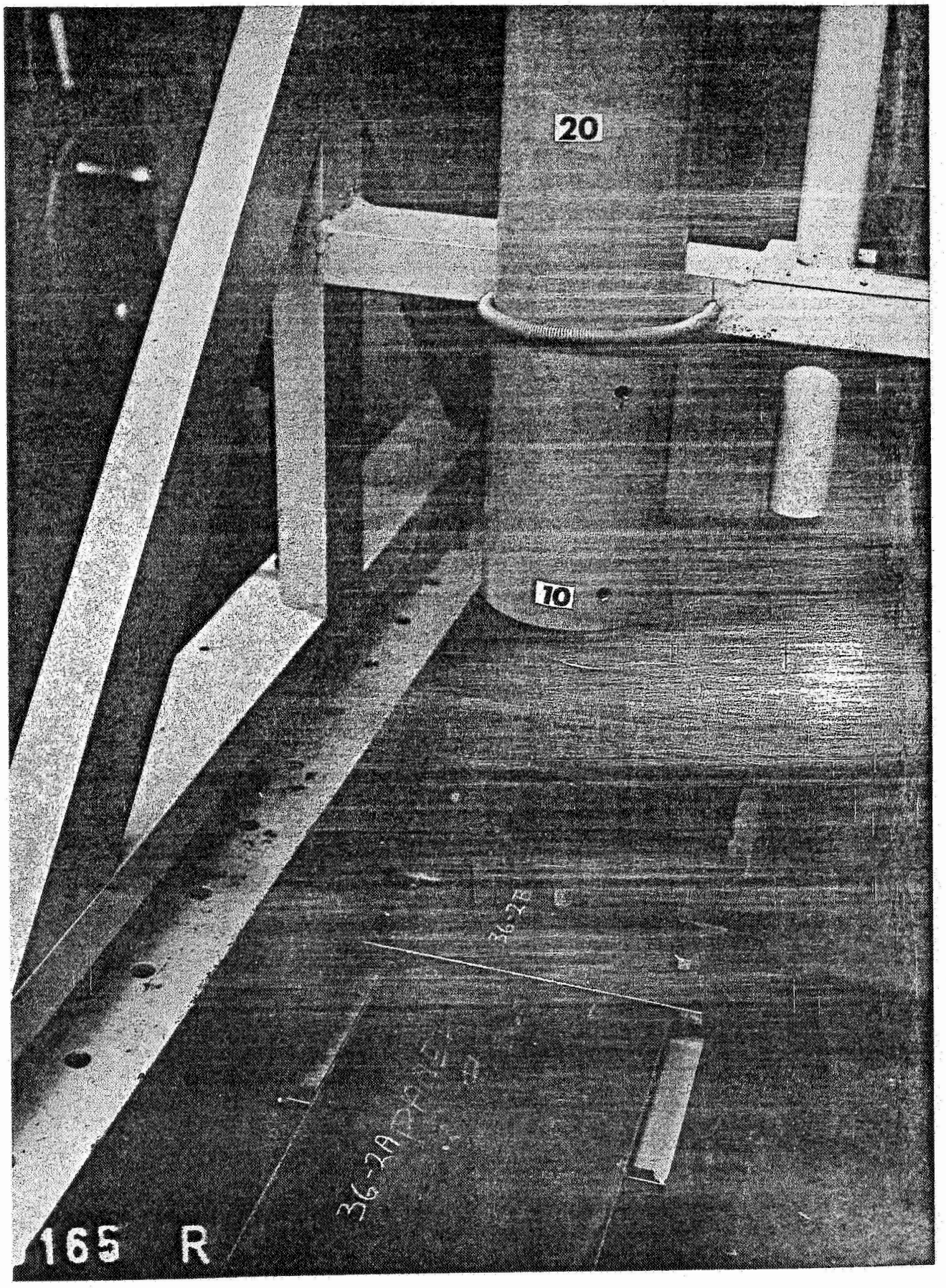


Figure 2-2: Detail View of Impactor Mass, Panel Tie-down Fixture and Panel.

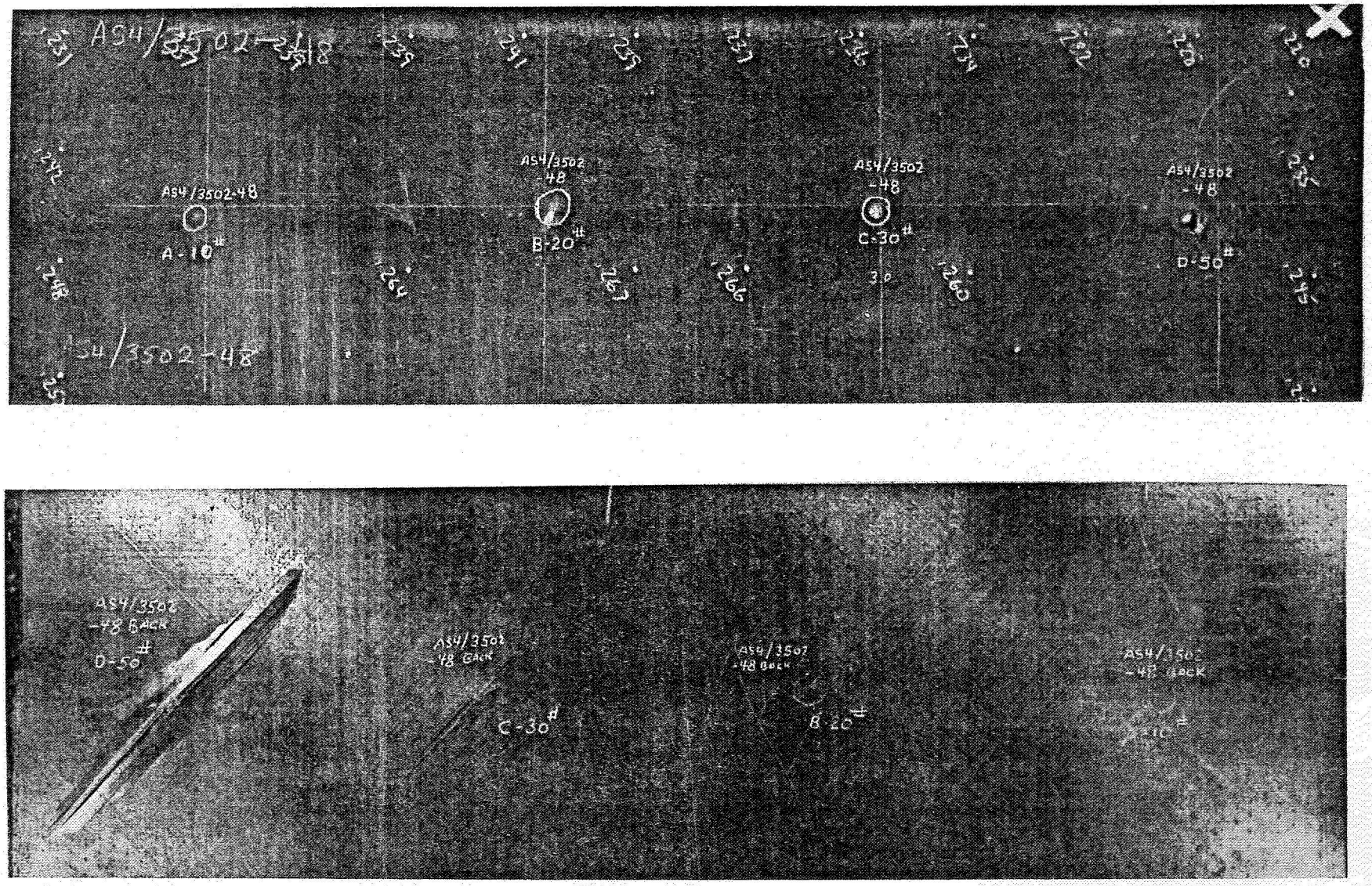


Figure 2-3: Front and Back View of a 7 X 25 Inch 48-Ply AS4/3502 Trial Impact Panel at 50, 30, 20 and 10 Ft.-Lbs. Impact Energy.

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Figure 2-4: Front and Back View of a 7 X 25 Inch 48-Ply Celion/982 Trial Impact Panel at 20, 30, 50 and 80 Ft.-Lbs. Impact Energy.

TABLE 2.2 CELION/982 IMPACT DATA

Panel #13 48 Plies $(45^{o}\ 0^{o}\ 135^{o}\ 90^{o})_{6S}$ t_{avg} = 0.305 Resin Content = 36.3%							
			C-Scan Damage			Visual Damage	
Panel I.D.	Test Type	Impact Energy (ft-lbs)	Length (in.)	Width (in.)	Area ($in.^2$)	Front ①	Back
2-4-13A	Compression	20	1.90	1.78	2.61	Slight dent	None
2-4-13B	Compression	20	2.00	1.90	2.94	Slight dent	None
2-5-13A	Compression	20	1.58	1.50	1.82	Slight dent	None
1-1-13A	Trial impact	20	1.90	2.00	2.98	Slight dent (0.0055)	None
1-1-13B	Trial impact	30	2.12	2.00	3.34	Dent (0.0095)	Slight delam.
1-1-13C	Trial impact	50	2.38	2.52	4.88	Large Dent (0.0830)	Major delam.
1-1-13D	Trial impact	80	4.14	4.48	13.66	Partial penetration of panel (0.2230)	
1-2-13A	Trial impact	10	0	0	0	None (0.0010)	None
1-2-13B	Trial impact	20	1.64	1.64	2.03	Slight dent (0.0065)	None
1-2-13C	Trial impact	30	2.34	2.34	4.10	Slight dent (0.0080)	1" Delam.
1-2-13D	Trial impact	40	2.72	2.76	5.54	Dent (0.0105)	None
1-3-13A	Trial impact	10	0.33	0.25	0.06	None	None
1-3-13B	Trial impact	20	1.49	1.50	1.63	Slight dent	None
1-3-13C	Trial impact	25	2.27	2.12	3.44	Slight dent	None
1-3-13D	Trial impact	30	2.63	2.70	5.42	Dent	None

① Measured dent depth (in.)

TABLE 2.3 AS4/2220-1 IMPACT DATA

Panel #12 48 Plies $(45^{o}\ 0^{o}\ 135^{o}\ 90^{o})_{6S}$ t_{avg} = 0.264 Resin Content = 34.3%

Panel #10A 96 Plies $(45^{o}\ 135^{o}\ 90^{o}\ 0^{o})_{12S}$ t_{avg} = 0.532 Resin Content = 36.0%

Panel I.D.	Test Type	Impact Energy (ft-lbs)	C-Scan Damage			Visual Damage	
			Length (in.)	Width (in.)	Area ($in.^2$)	Front ①	Back
2-4-12A	Compression	20	1.64	1.40	1.81	Slight dent	None
2-4-12B	Compression	20	1.68	1.50	2.02	Slight dent	None
2-5-12A	Compression	20	1.76	1.47	1.99	Slight dent	None
1-3-12A	Trial impact	10	1.25	1.19	1.14	None	None
1-3-12B	Trial impact	20	1.73	1.57	2.05	Slight dent	None
1-3-12C	Trial impact	25	2.03	1.90	2.89	Slight dent	None
1-3-12D	Trial impact	30	2.18	2.18	3.74	Dent	½" Delam.
1-1-12A	Trial impact	20	1.68	1.50	2.00	Slight dent (0.0060)	None
1-1-12B	Trial impact	30	1.90	2.00	2.97	Dent (0.0095)	2" Delam.
1-1-12C	Trial impact	50	1.98	2.13	3.38	Partial penetration (0.1500)	Major Delam.
1-1-12D	Trial impact	80	2.18	2.20	3.83	Full penetration of panel	
1-2-12A	Trial impact	10	1.12	0.98	0.84	None	None
1-2-12B	Trial impact	20	1.70	1.54	2.02	None	None

① Measured dent depth (in.)

TABLE 2.3 AS4/2220-1 IMPACT DATA (Continued)

Panel #12 48 Plies $(45^{o}\ 0^{o}\ 135^{o}\ 90^{o})_{6S}$ t_{avg} = 0.264 Resin Content = 34.3%

Panel #10A 96 Plies $(45^{o}\ 135^{o}\ 90^{o}\ 0^{o})_{12S}$ t_{avg} = 0.532 Resin Content = 36.0%

Panel I.D.	Test Type	Impact Energy (ft-lbs)	C-Scan Damage			Visual Damage	
			Length (in.)	Width (in.)	Area ($in.^2$)	Front ①	Back
1-2-12C	Trial impact	30	2.10	2.14	3.25	Slight dent	1¼" Delam.
1-2-12D	Trial impact	40	2.56	2.68	4.86	Large dent	3" Delam.
PV-10A-A	Trial impact	20	0.58	0.50	0.22	Slight dent (0.0015)	None
PV-10A-B	Trial impact	30	2.90	3.16	7.11	Dent (0.0115)	None
PV-10A-C	Trial impact	50	2.95	3.15	7.41	Dent (0.0080)	None
PV-10A-D	Trial impact	80	3.56	3.18	8.64	Partial penetration (0.0785)	None

① Measured dent depth (in.)

TABLE 2.4 AS4/3502 IMPACT DATA

Panel #8 96 Plies $(45^{o}\ 135^{o}\ 90^{o}\ 0^{o})_{12S}$ t_{avg} = 0.530 Resin Content = 37.2%

Panel #B/B4 48 Plies $(45^{o}\ 135^{o}\ 90^{o}\ 0^{o})_{6S}$ t_{avg} = 0.260 Resin Content = 34.8%

Panel I.D.	Test Type	Impact Energy (ft-lbs)	C-Scan Damage			Visual Damage	
			Length (in.)	Width (in.)	Area (in.^{2})	Front ②	Back
8-AS4/3502-96A	Trial impact	20	0.60	0.60	0.26	Slight dent (0.0045)	None
8-AS4/3502-96B	Trial impact	30	3.40	3.20	8.01 ①	Dent (0.0080)	None
8-AS4/3502-96C	Trial impact	50	3.17	3.35	7.41	Penetration (0.0395)	None
8-AS4/3502-96D	Trial impact	80	3.86	3.90	11.42	Penetration	2" Delam.
B/B4-AS4/ 3502-48A	Trial impact	10	1.55	1.50	1.72	Slight dent (0.0010)	None
B/B4-AS4/ 3502-48B	Trial impact	20	1.60	1.76	2.18	Medium dent (0.0055)	1" Delam.
B/B4-AS4/ 3502-48C	Trial impact	30	1.90	1.87	2.74	Large dent (0.0095)	4½" Delam.
B/B4-AS4/ 3502-48D	Trial impact	50	1.80	1.90	3.09	Penetration (0.0485)	6" Delam.

① Molded panel I.D. interference

② Measured dent depth (in.)

2.2, 2.3, and 2.4, list under "front surface visible damage" the measured depth values in parentheses for the available panels. Figure 2-5 shows a plot of impact energy versus impact dent depth for both 48 and 96 ply laminates. No major differences in dent depth are noted between any of the panels up through 30 ft. lbs. Beyond that level, as expected, the 96 ply laminates exhibit less denting.

Figures 2-6, 2-7, and 2-8 show close-ups of typical visible impact characteristics on a 48-ply AS4/2220-1 panel. The scale in all photos is in inches. Figures 2-9, 2-10, and 2-11 show similar results on a 48-ply AS4/3502 panel. Figures 2-12 and 2-13 show 50 and 80 ft. lb strikes on a 96-ply AS4/2220-1 panel. Visible damage is confined only to the front surface even at 80 ft. lbs. for the 96-ply AS4/2201-1 panel where partial penetration has occurred. Partial penetration on the 48-ply panels produced major back surface delamination as shown in Figure 2-11.

Ultrasonic C-scans were made of all impacted panels. Defining delamination damage as the C-scan indicated region, C-scan shows much greater damage than visual techniques. Tables 2.2, 2.3, and 2.4 list length, width, and area of the C-scan indications. Areas of delamination of up to 2 square inches occur with no visible damage on either surface. Figures 2-14, 2-15, and 2-16 plot damage area versus impact energy. As previously shown the visual damage threshold was between 20 and 30 ft. lbs. whereas the C-scan damage threshold for Ceilon/982 in Figure 2-14 is approximately 10 ft. lbs. For AS4/2220-1 and AS4/3502 in Figures 2-15 and 2-16 the C-scan damage threshold is around 5 ft. lbs. Therefore significant internal delamination can be produced by impact in a panel without any visible external indications.

A section was made through the center of a 96-ply AS4/3502 panel impacted at 80 ft.-lbs. (specimen 8-AS4/3502-96D) to obtain a comparison of C-scan damage indications with optical microscopy techniques. Visual external damage was partial penetration of the front surface and a 2-inch delamination on the back surface. C-Scan results indicated a delamination

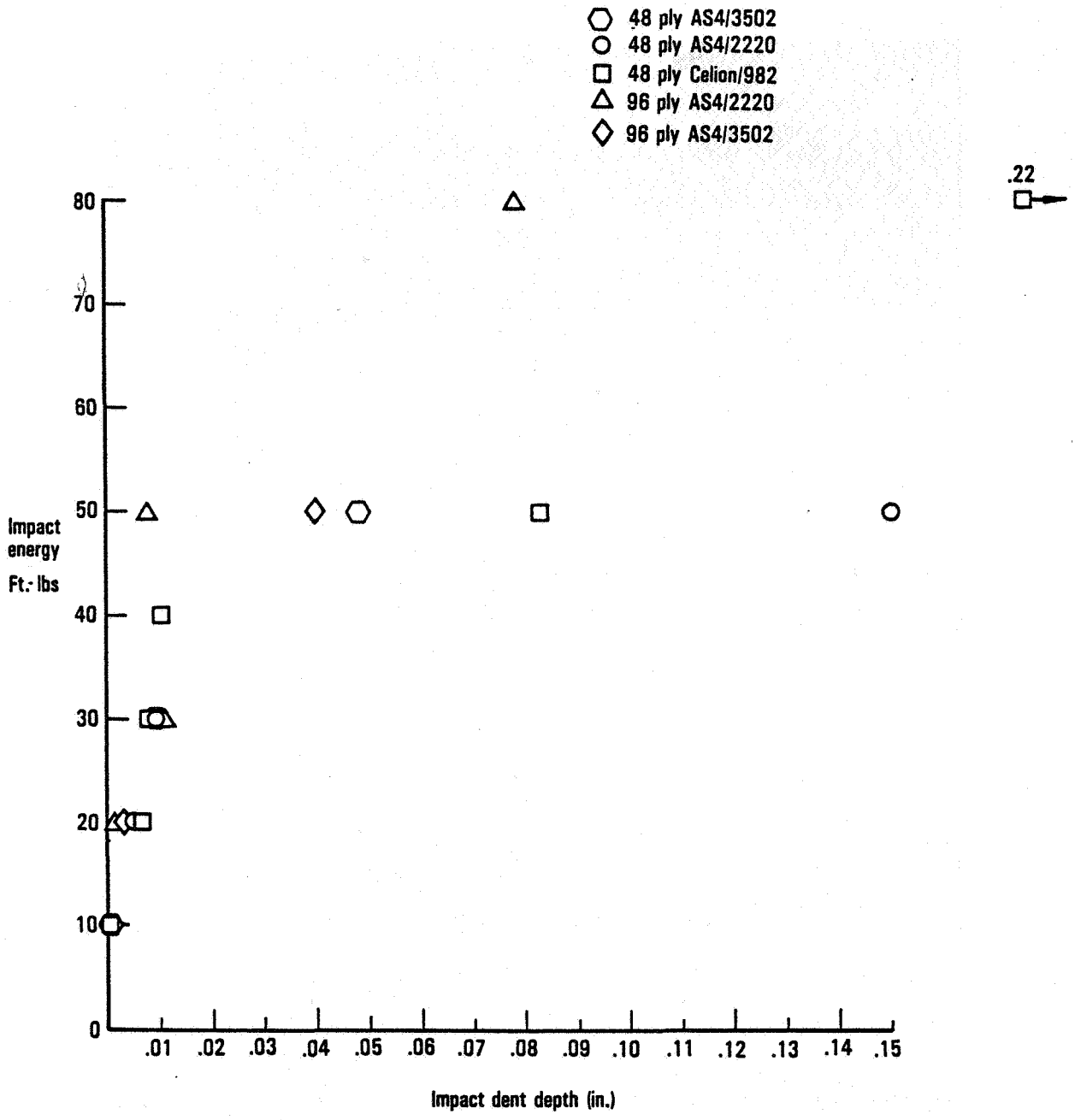


Figure 2-5: Impact Dent Depth versus Energy.

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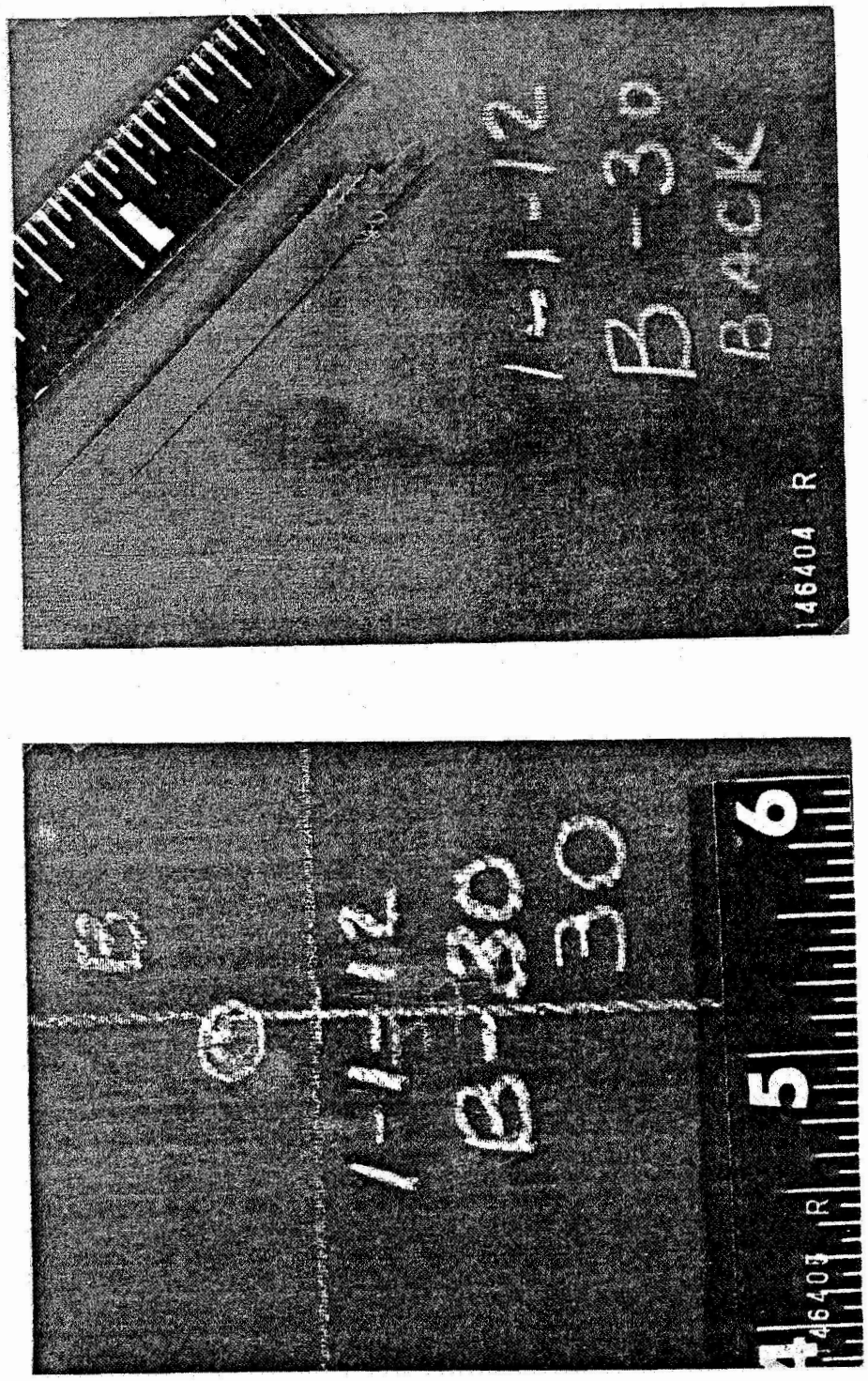


Figure 2-6: Front and Back Surface Damage on 48-Ply AS4/2220-1 Panel Impacted at 30 Ft.-Lbs. Dent on Front Surface and 2" Delamination on Back Surface.

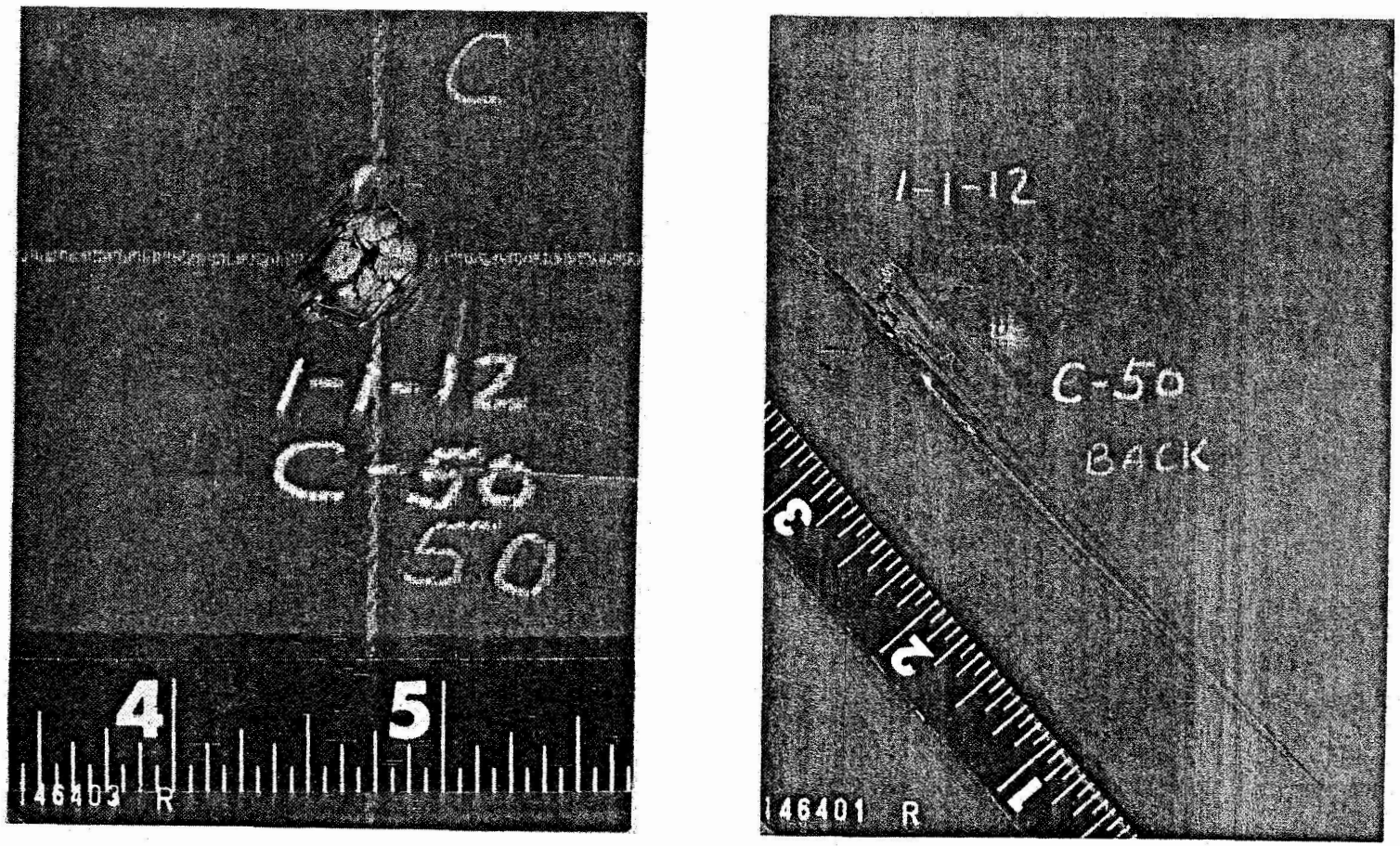


Figure 2-7: 50 Ft.-Lb. Impact Damage on a 48-Ply AS4/2220-1 Panel. Front Surface Shows Partial Penetration and the Back Surface Has Major Delamination. The Scale is in Inches.

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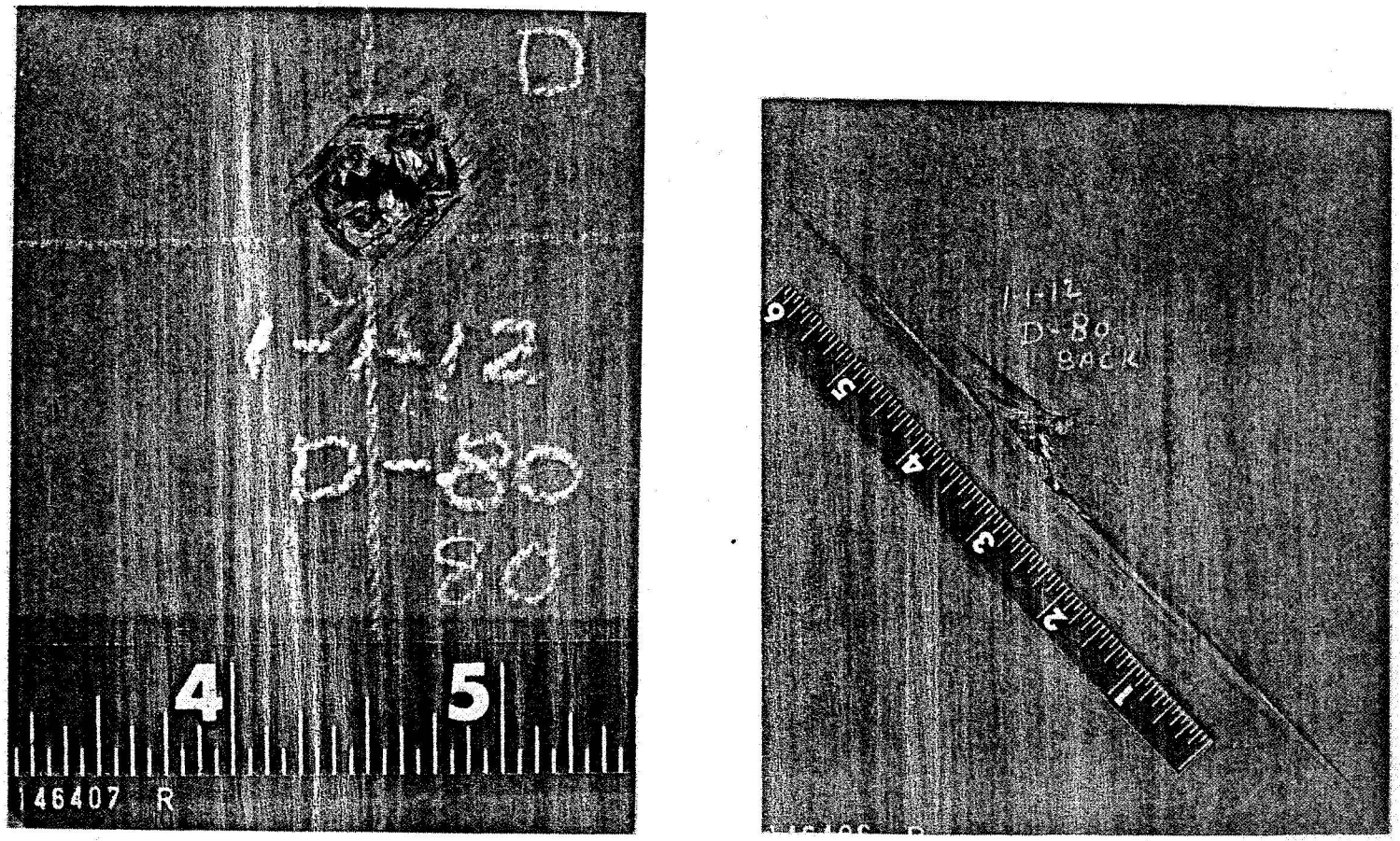


Figure 2-8: 80 Ft. Lb. Impact Damage on a 48-Ply AS4/2220-1 Panel. The Impactor Tip Fully Penetrated Through the Panel.

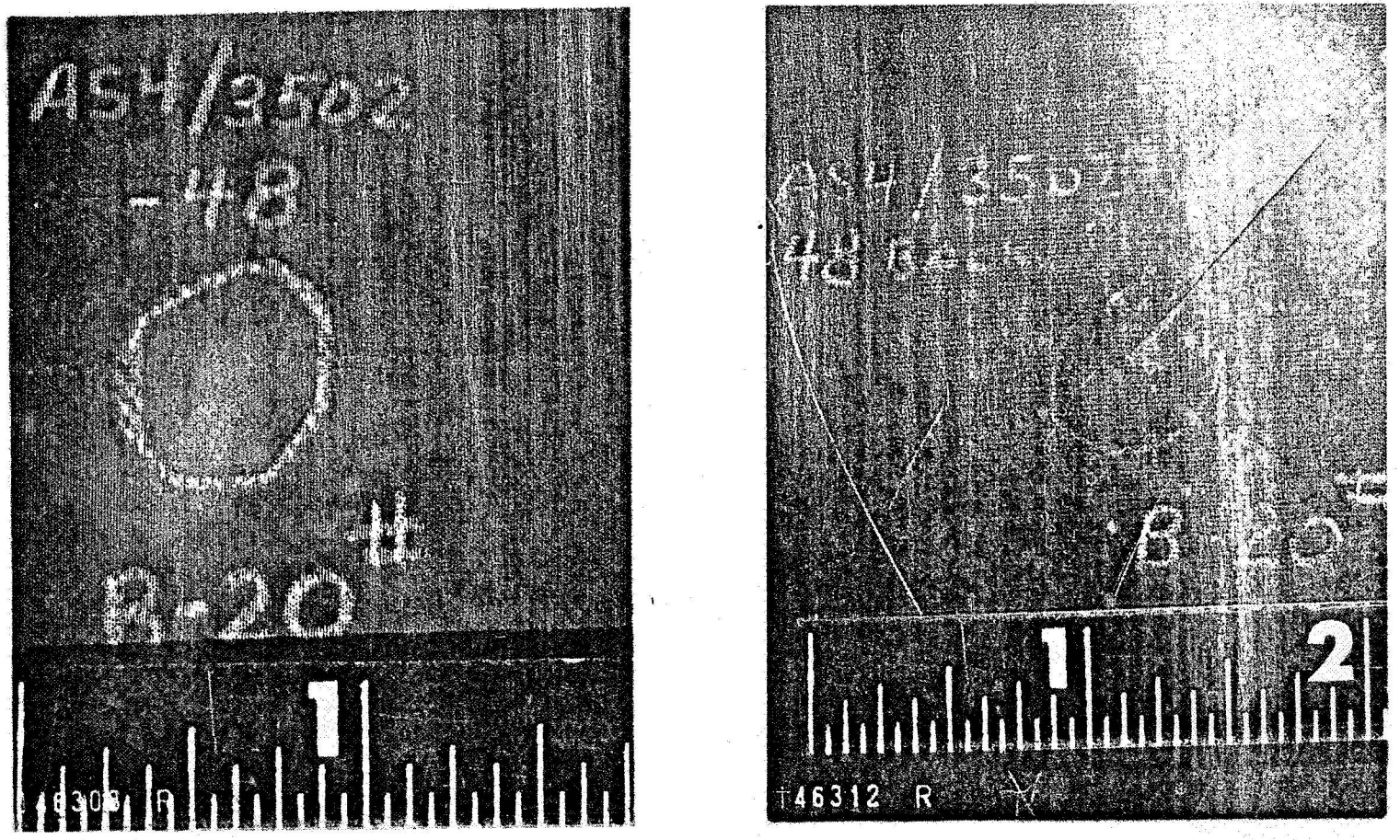


Figure 2-9: 20 Ft. Lb. Impact Damage on a 48-Ply AS4/3502 Panel. The Front Surface Has a Medium Dent and the Back Surface a 1" Delamination.

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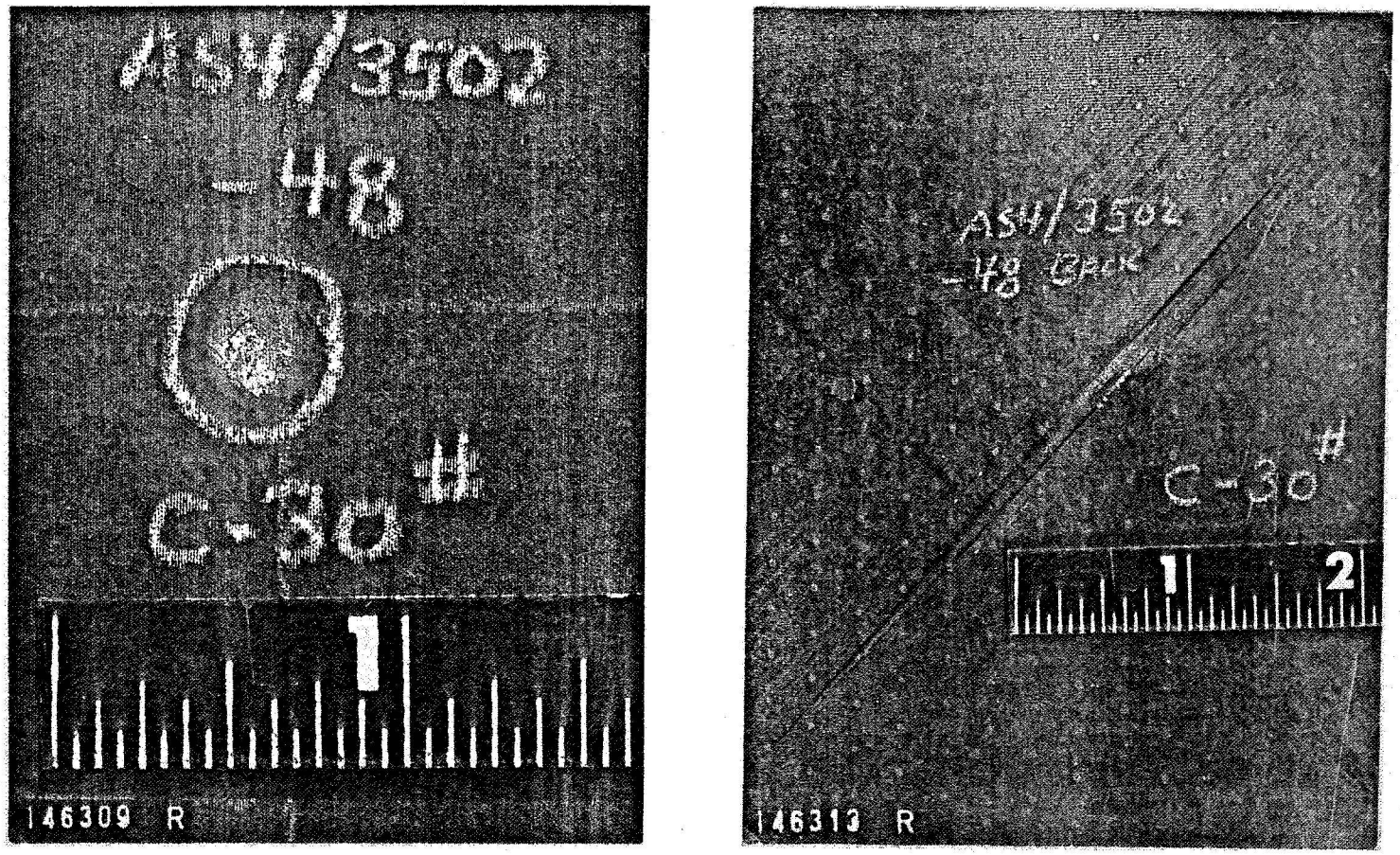
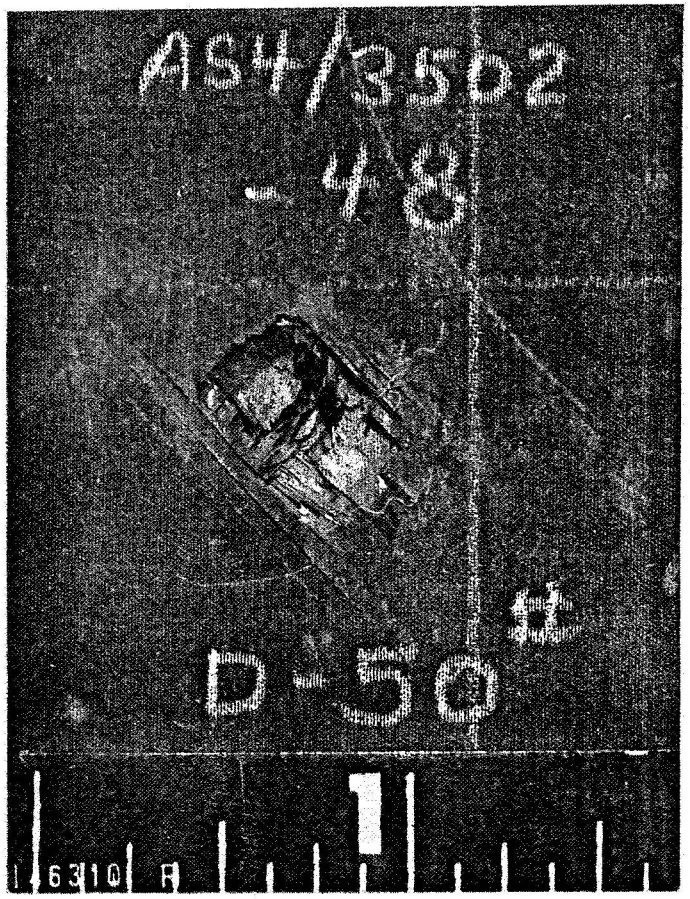
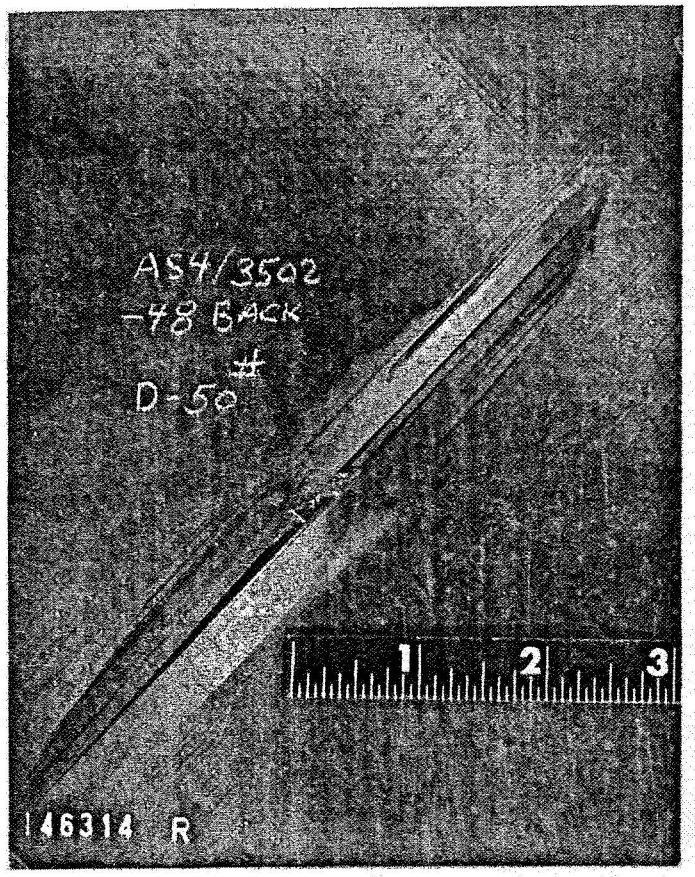


Figure 2-10: 30 Ft. Lb. Impact Damage on a 48-Ply AS4/3502 Panel. The Front Surface Shows a Large Dent With Broken Fibers, The Back Surface has a 4½-Inch Delamination.

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Figure 2-11: 50 Ft. Lb. Impact Damage on a 48-Ply AS4/3502 Panel. The Impactor Tip Has Penetrated the Front Surface and Produced a 6-Inch Delamination on the Back Surface.

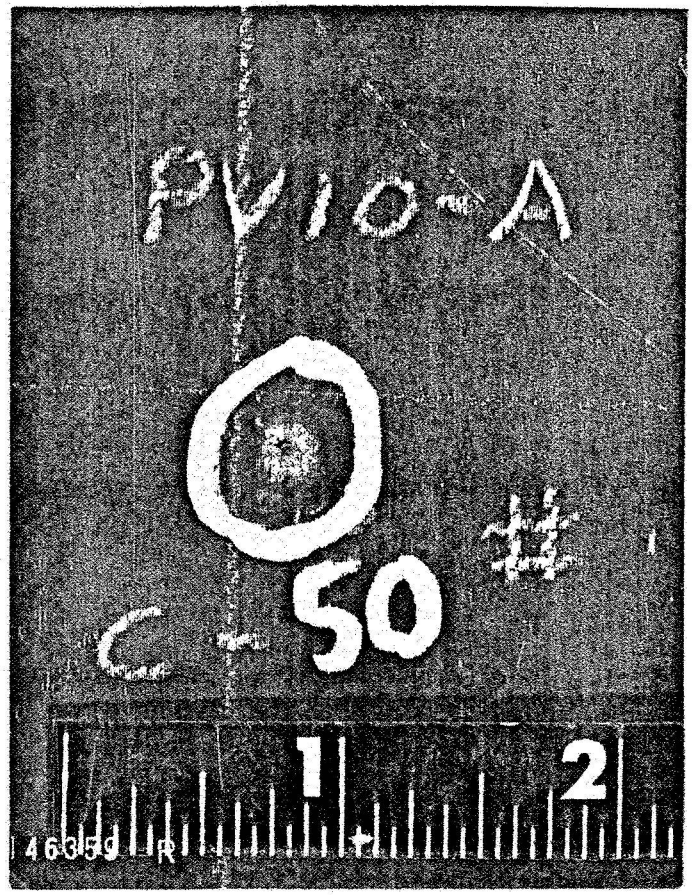


Figure 2-12: 50 Ft. Lb. Impact Damage on the Front Surface of a 96-Ply AS4/ 2220-1 Panel

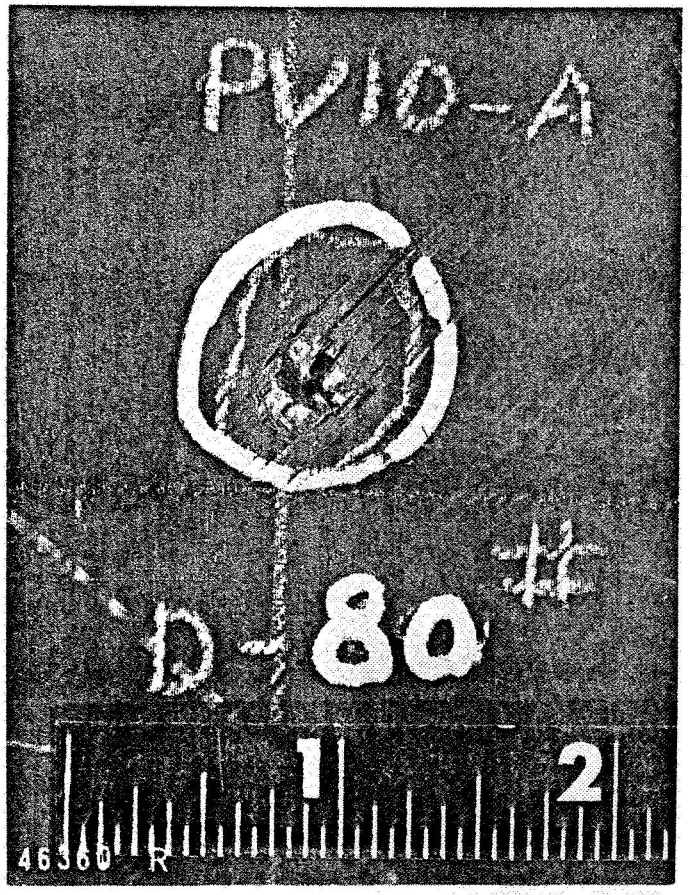


Figure 2-13: 80 Ft. Lb. Impact Damage on the Front Surface of a 96-Ply AS4/ 2220-1 Panel. Back Surface has No Damage.

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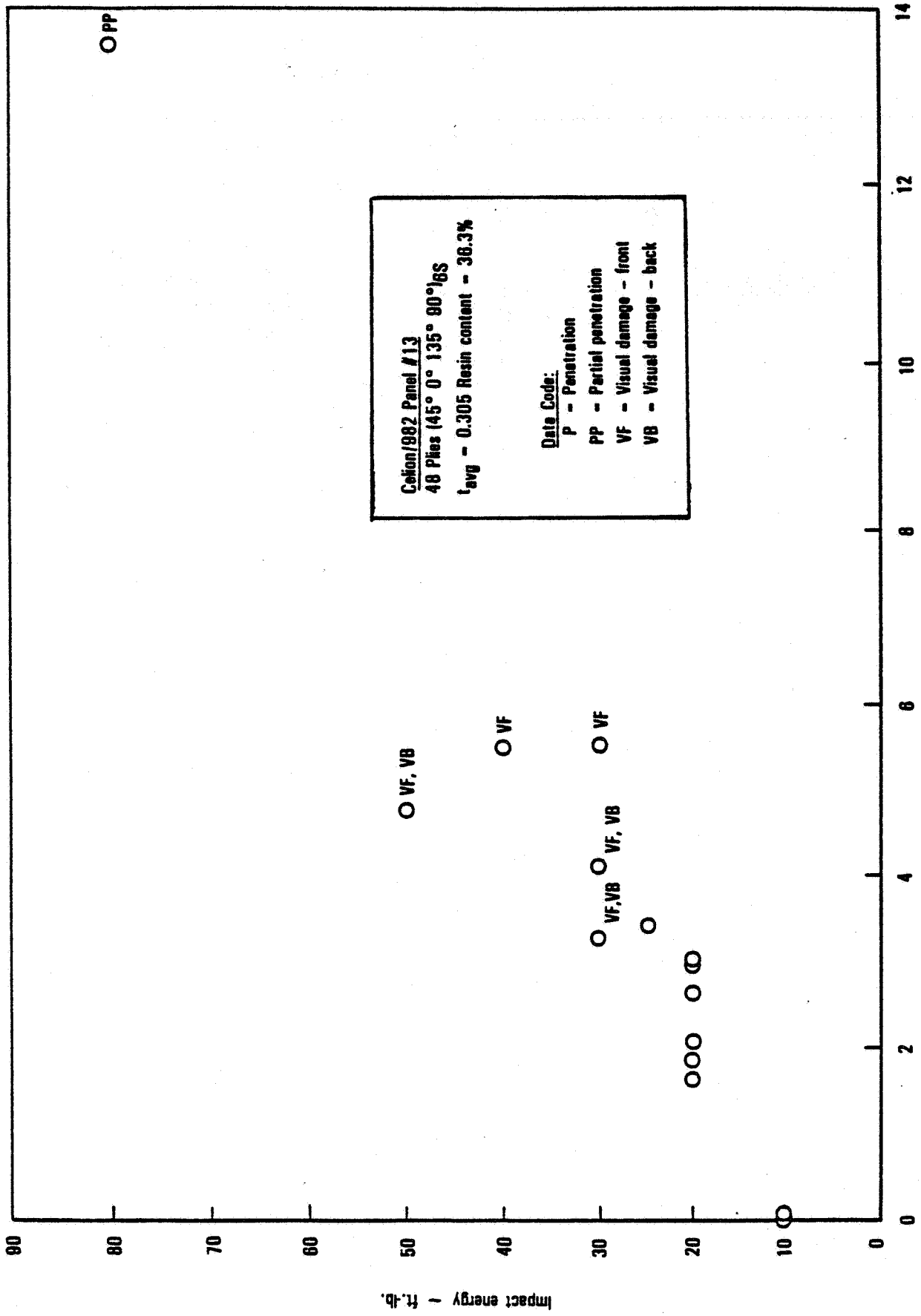


Figure 2-14 - Celion/982 impact data.

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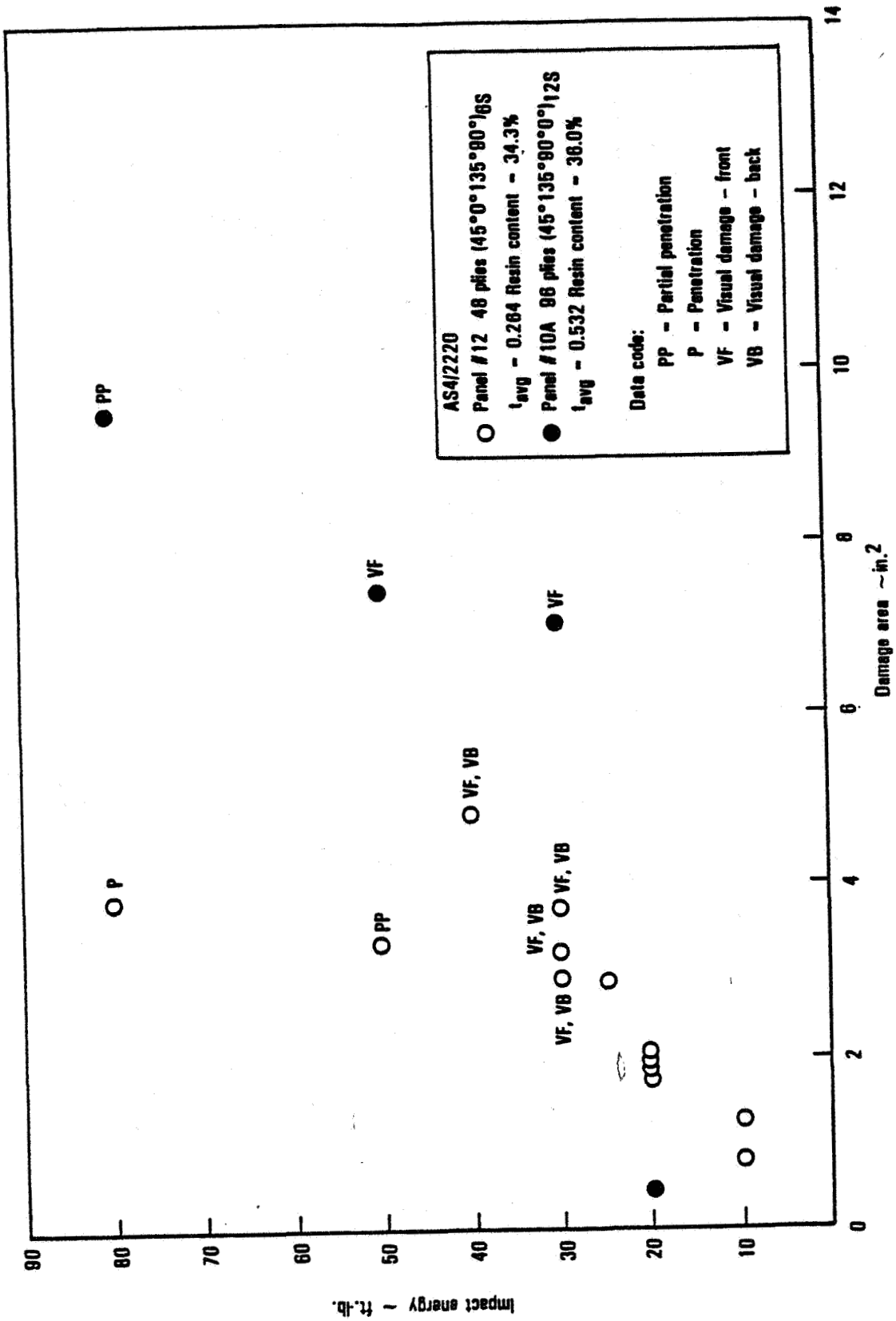


Figure 2-15 - AS4/2220 Impact data.

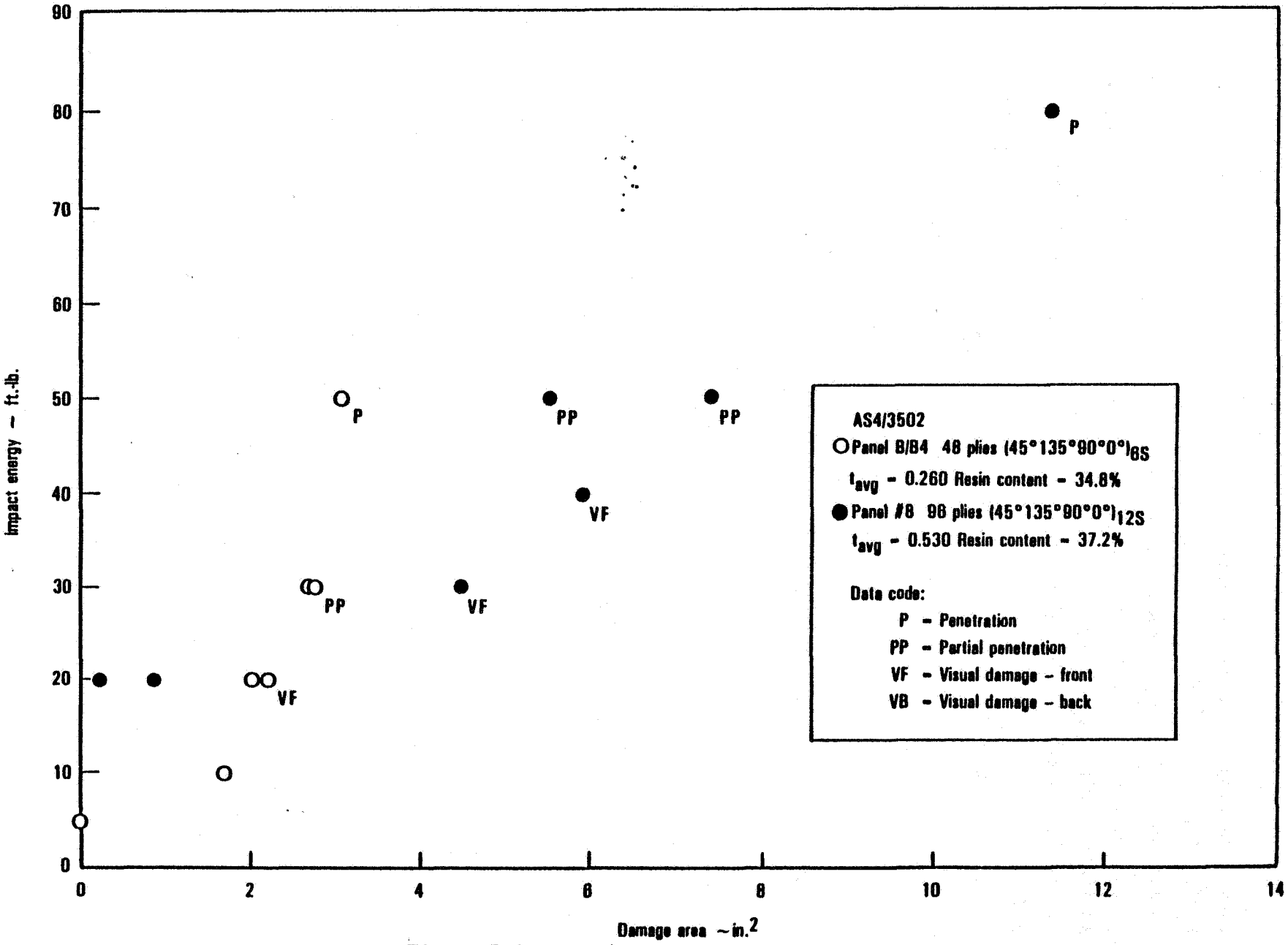


Figure 2-16 - AS4/3502 impact data.

3.86 inch long by 3.90 inch wide with an area of 11.42 square inch. (Table 2.4). Figure 2-17 shows a 1X and 2.45X view of the sectioned and polished impact area. The arrow indicates the point of impact. Figure 2-18 is a 10X micrograph of the section showing extensive cracking throughout the laminate. Many of the delaminations have been filled with mounting resin during the sample preparation which makes it difficult to see the full extent of delamination. Figures 2-19 through 2-23 show sectional micrographs of various locations in the sample. The largest crack was found in the 87th ply extending 4.08 inches. This correlates very well with the C-scan indications of 3.9 inches.

The mating half of the sectional piece was ultrasonically cleaned and brushed several times then soaked in a gold chloride solution prior to a vacuum burn-out technique. Each ply was then removed and examined for the extent of gold chloride penetration into the delamination areas as a comparison technique with optical microscopy for determining the extent of delamination. Results were quite poor compared to the optical technique; penetration rarely reach to half of the expected or optically measured depth of the cracks.

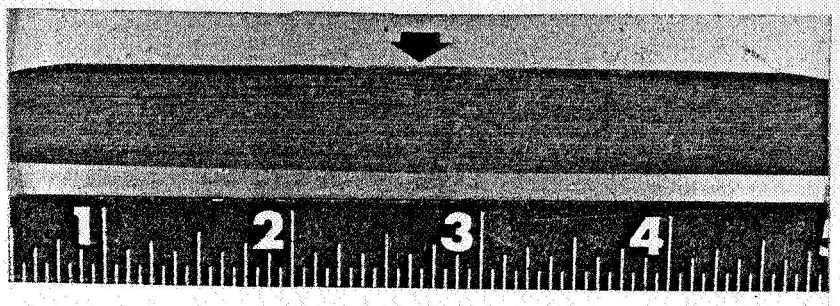
2.3 COMPRESSION TESTS

Based on the results of the trial impact tests an impact energy of 20 ft. lbs. was selected for evaluating impacted compression strength. Additional compression tests were conducted on specimens with a 1.0-inch diameter center notch.

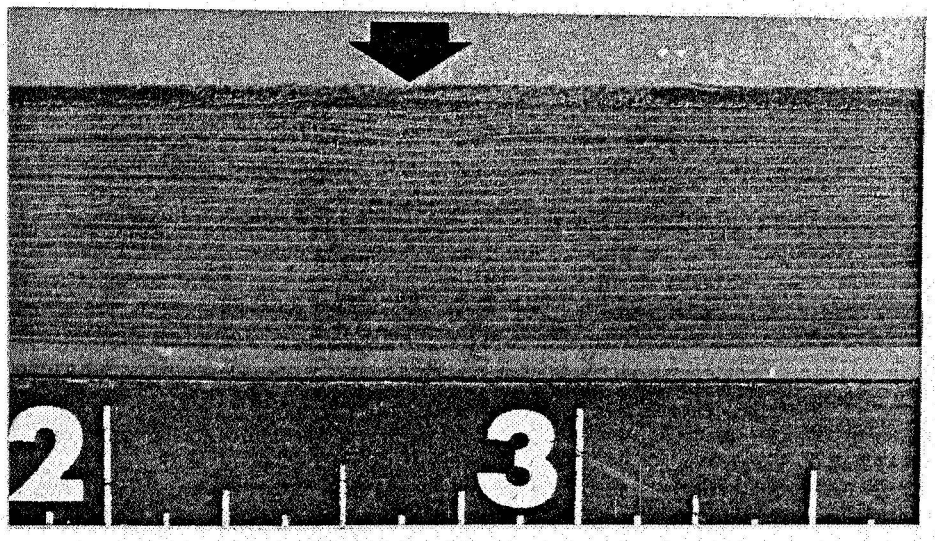
Panels were cut into 7 X 25 inch sub-panels, as shown in Figure 2-24, from which specimens were subsequently removed depending on the type of test desired. Specimens were impacted in the 7 X 25 sub-panel geometry prior to machining to the final 5 X 12 inch specimen size so that the impact zone could be located more precisely in the specimen center. The compression specimen geometry is shown in Figure 2-25. The most critical tolerance on

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IMPACT



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2.45X

Figure 2-17: Section of a 96-Ply AS4/3502 Panel Impacted at 80 Ft.-Lbs. Dimensions in Inches.

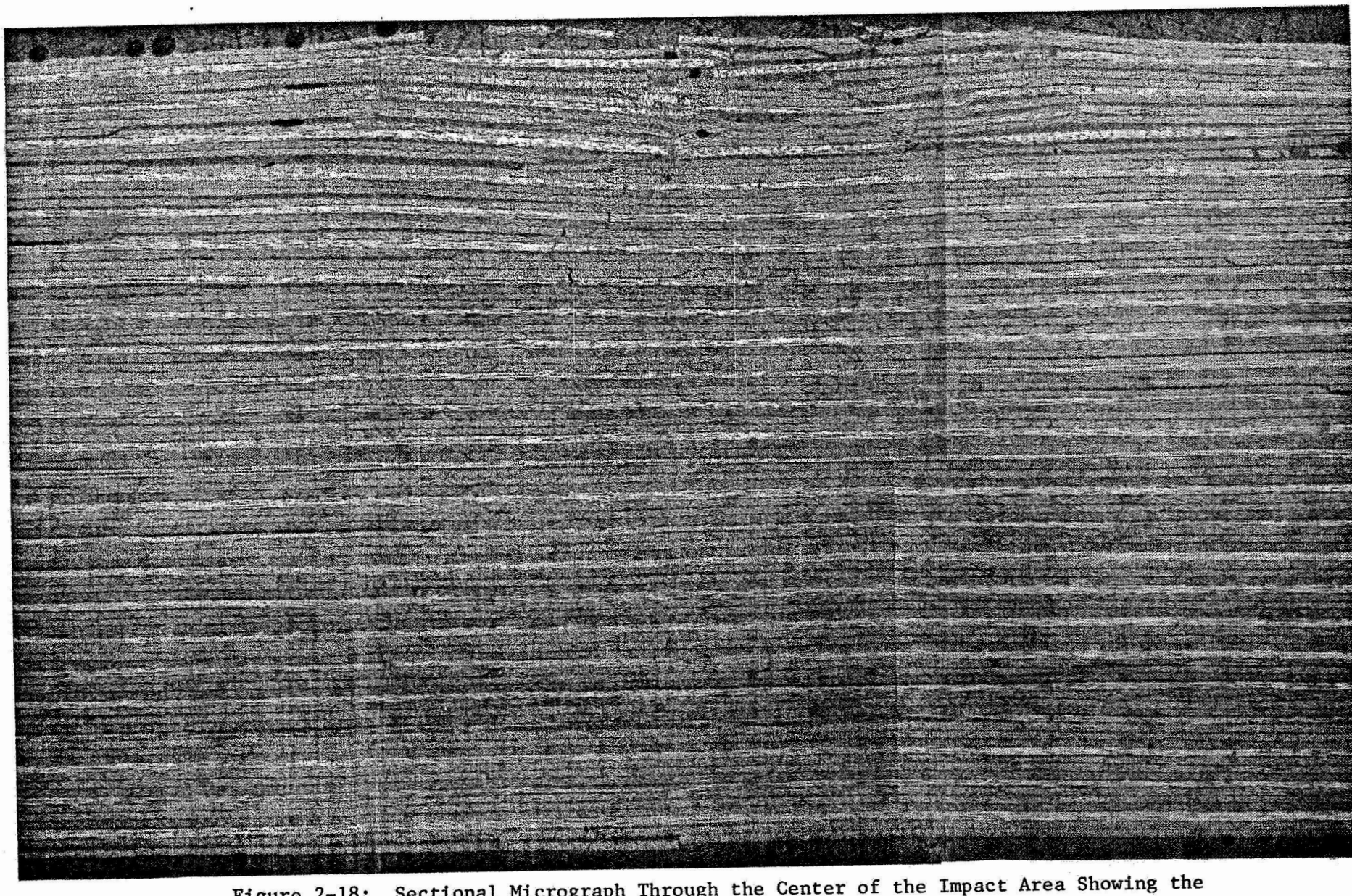
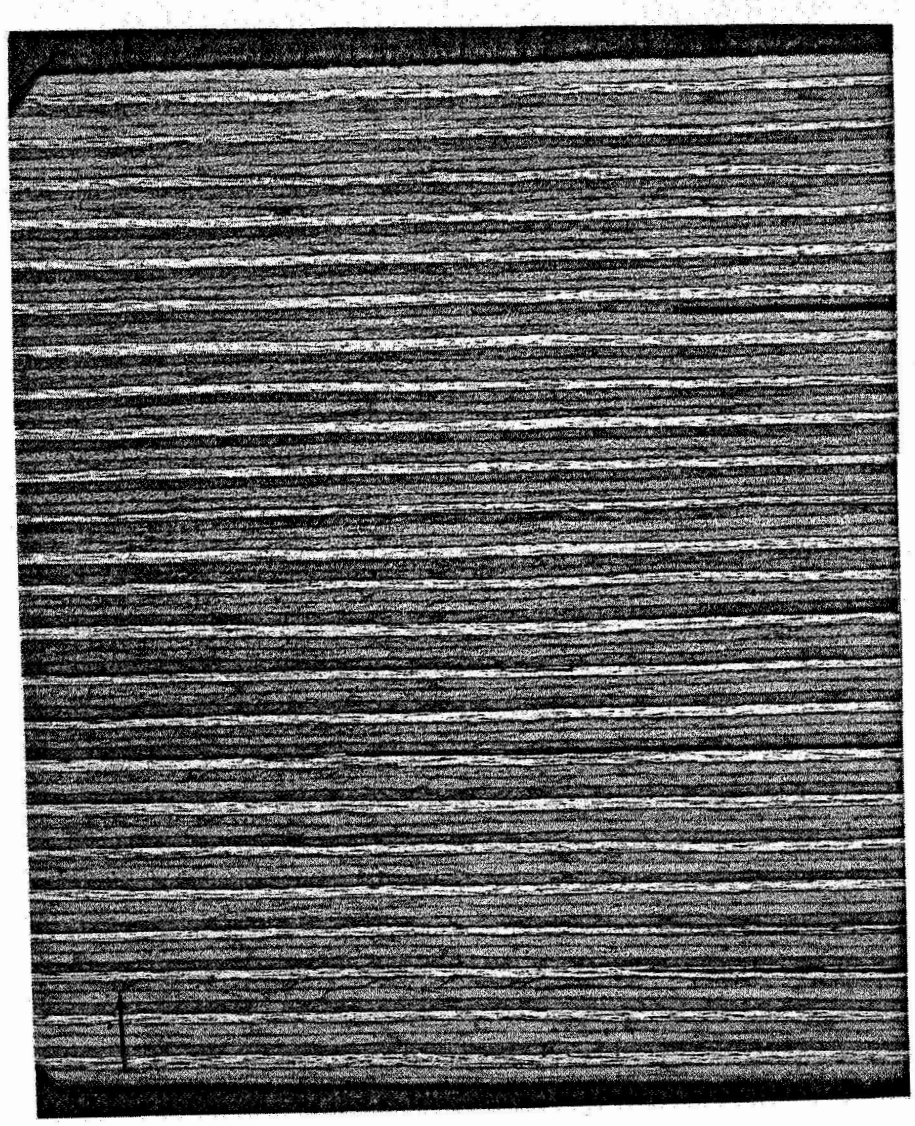


Figure 2-18: Sectional Micrograph Through the Center of the Impact Area Showing the Extent of Damage Through the Thickness of the Panel.

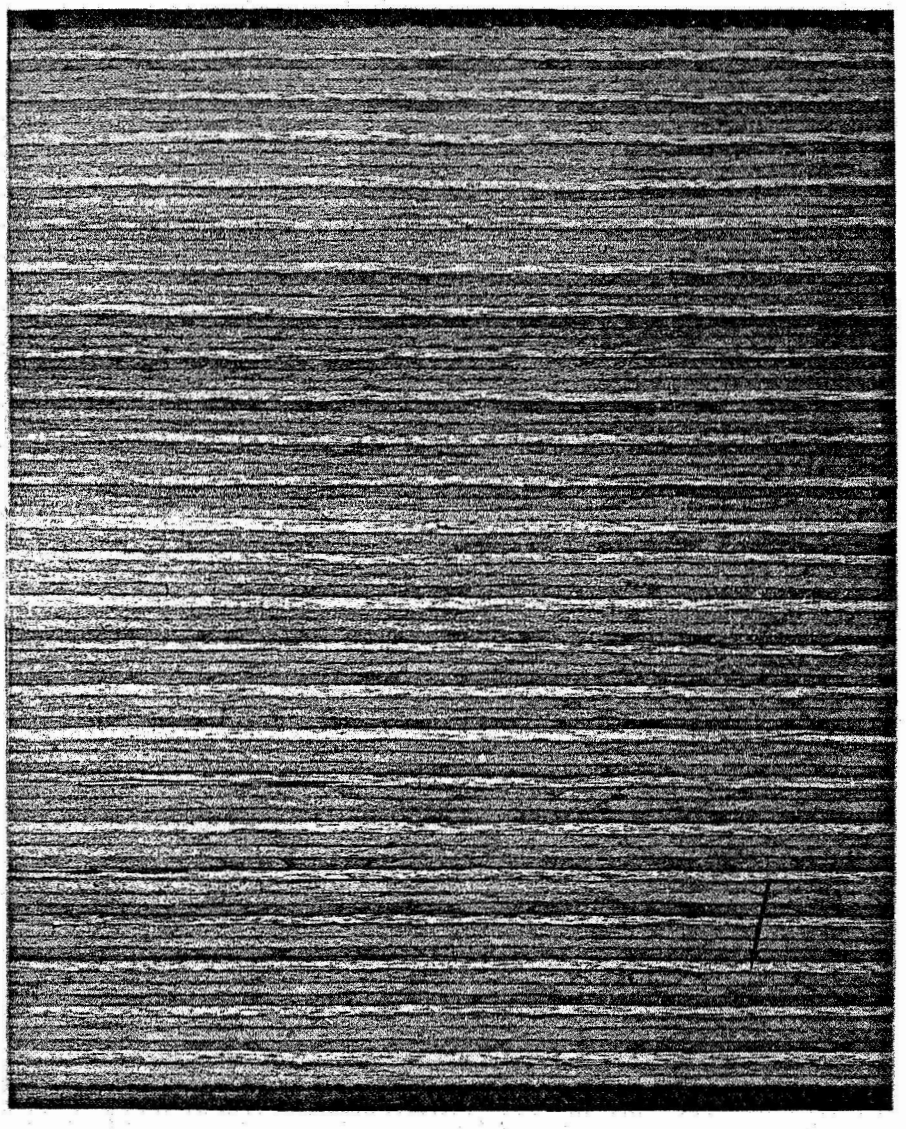
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10X

Figure 2-19: Left Extreme Most Area of Cracking Found in the 87th Ply.



10X

Figure 2-20: Right Extreme Most Area of Cracking Found in the 87th Ply.

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Figure 2-21: Closeup of Cracks at the Most Extreme Left and Right Side of the Section. Most Cracks are in the 87th Ply.

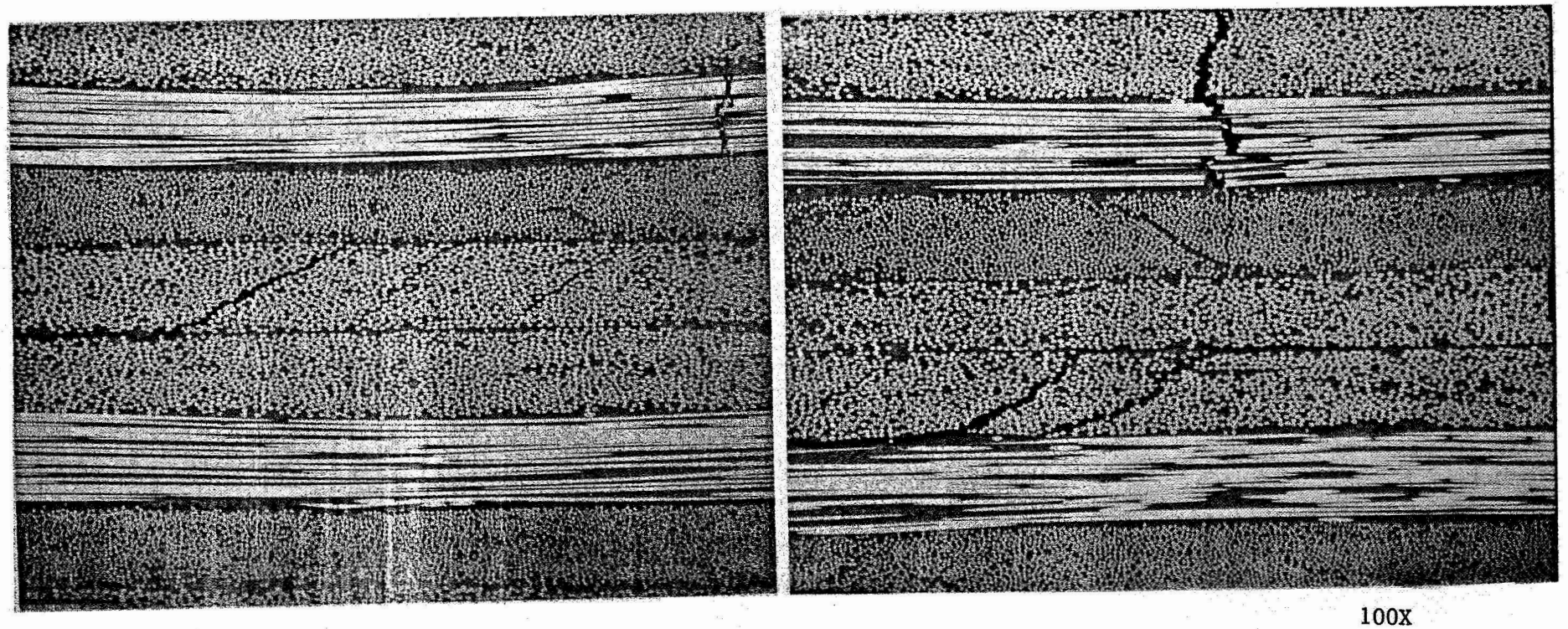
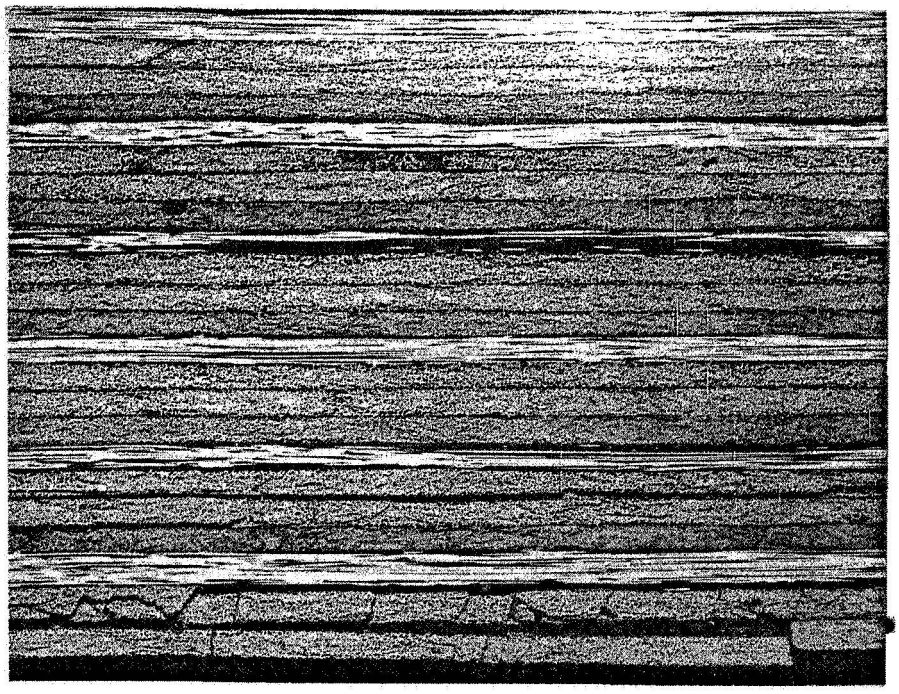


Figure 2-22: Closeup of Typical Cracks and Delaminations Found In the Center of Impact.

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25X



25X

Figure2-23: Closeup of the Cracks and Delaminations in The Center of Impact Area.

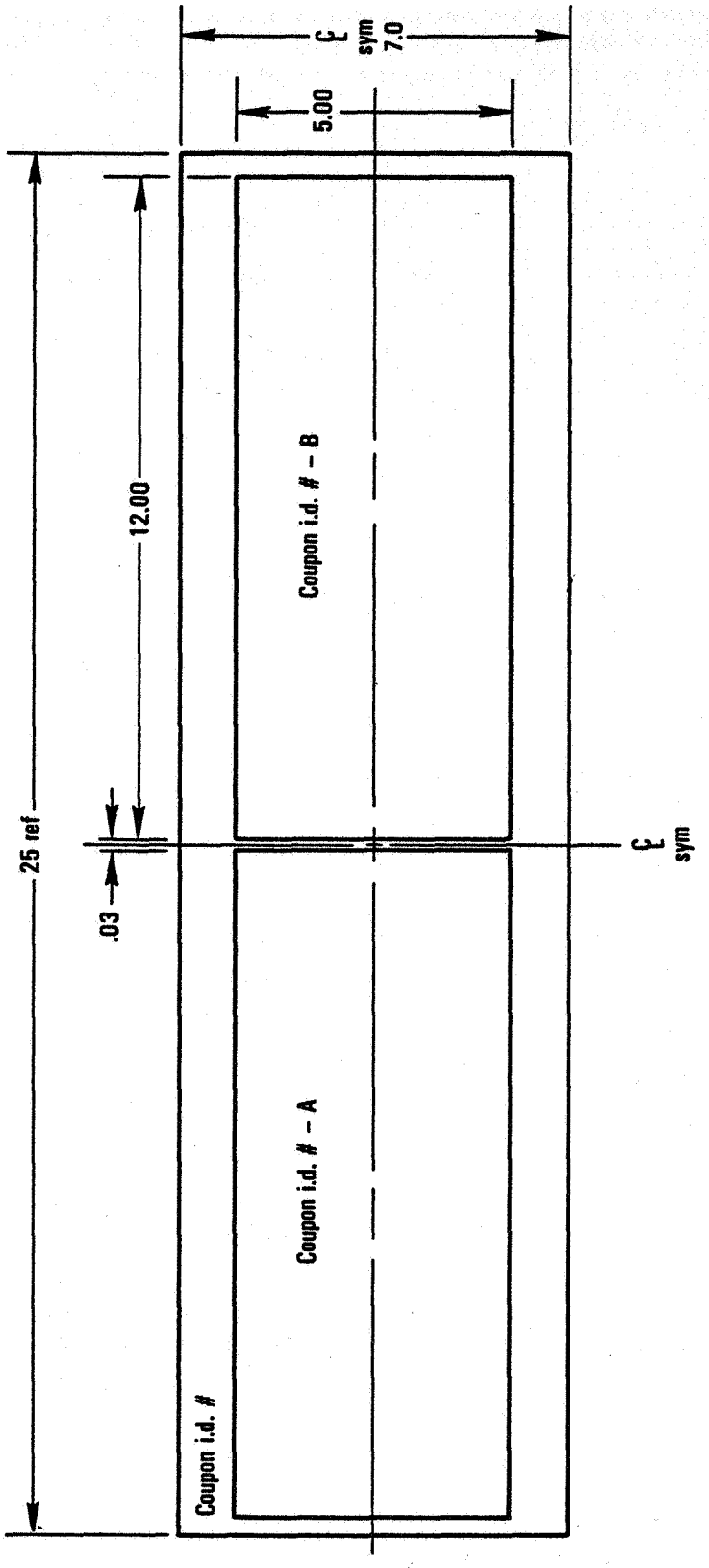


Figure 2-24: Compression Subpanel

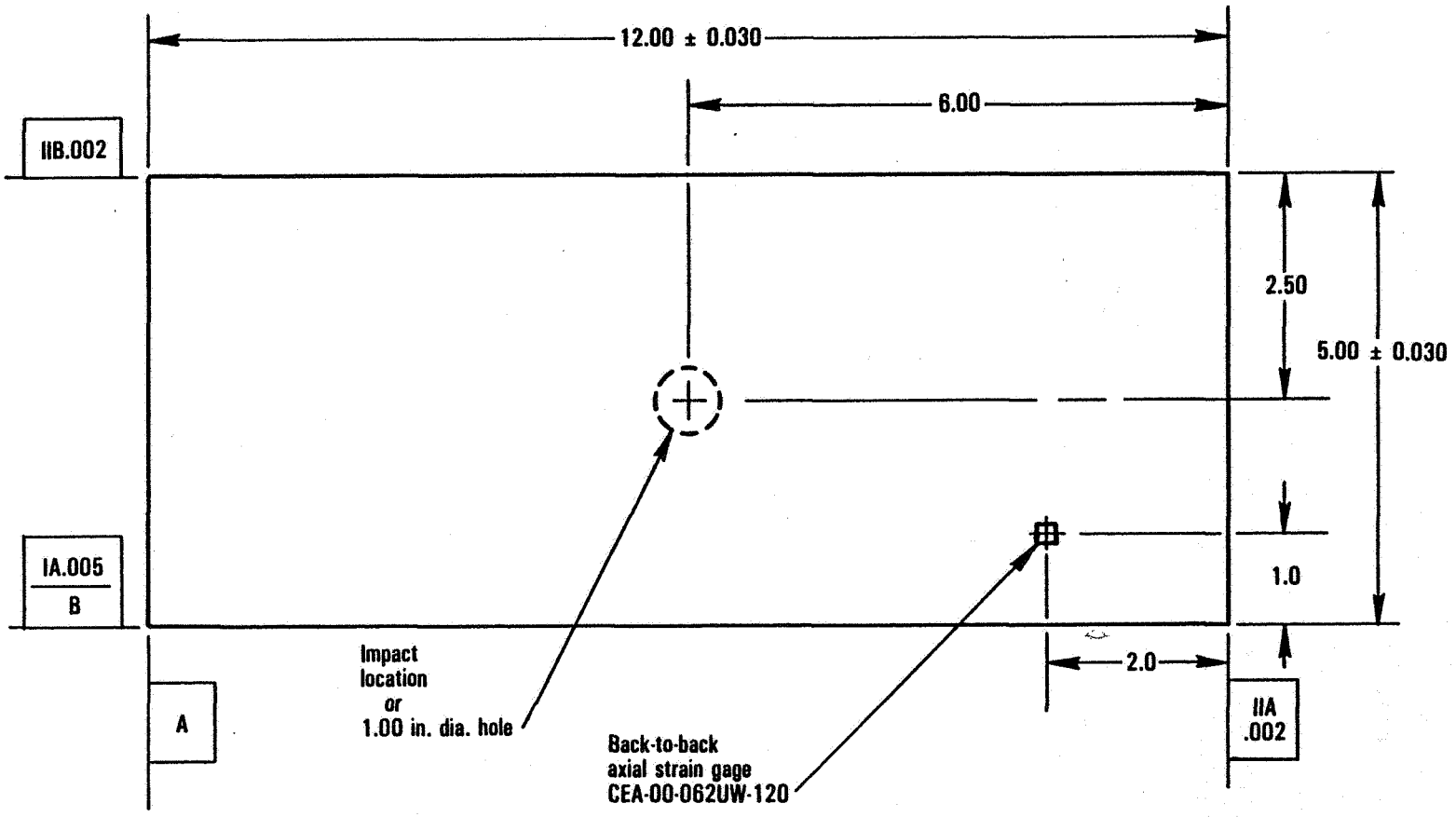


Figure 2-25: Compression Coupon

this specimen for the type of test fixture employed was maintaining the bearing ends (A) parallel to within 0.002 inch.

After machining, back-to-back axial strain gages were installed near one corner. These gages were CEA-00-062-UW-120 gages bonded at room temperature with AE 10 adhesive. No coating was applied over the gages.

Two laminates, AS4/2220-1 and Celion/982, with a laminate orientation of $(45^{\circ}/0^{\circ}/135^{\circ}/90^{\circ})_{6s}$ were tested. Four types of tests were performed on each: 1) 1.0 inch diameter hole at 75°F dry; 2) 1.0-inch diameter hole at 180°F conditioned; 3) impacted at 20 ft.-lbs. at 75°F dry; and 4) undamaged 2-inch wide at 75°F dry. The conditioning cycle consisted of soaking in 160°F water for 45 days during which the AS4/2220-1 moisture travelers (1 x 1 inch) gained 0.89% average weight in 45 days and the Celion/982 travelers similarly gained 1.11%. Specimens to be conditioned had gages applied prior to conditioning, but the lead wires were not applied until after conditioning. Corrosion problems were still encountered and several gages had to be relaid after conditioning. Travelers accompanied the specimens during subsequent operations, but due to minimizing time out of sealed bags no significant changes in moisture level were noted.

An adjustable width compression fixture shown in Figures 2-26 through 2-30 was used for all 5-inch wide tests. Side edges of the specimens were snugly supported by 1/2-inch thick rounded nose plates shown in Figure 2-26. To allow for Poisson expansion in width, 0.020-inch shims were placed on either side of the specimen as shown in Figure 2-26 and then the side supports were brought up into snug contact and bolted down. The shims were then removed. Details of the top loading/support plate are shown in Figure 2-27. This plate was placed on the specimen, and the 1/2-inch thick side support plates were tightened to approximately 20 ft. lbs. Alignment of the top plate was achieved by guide slots on the outboard ends of the plate as seen in Figure 2-28. Likewise bottom width support plates were also tightened. The completed assembly is shown in Figure 2-29, and ready for test in Figure 2-30.

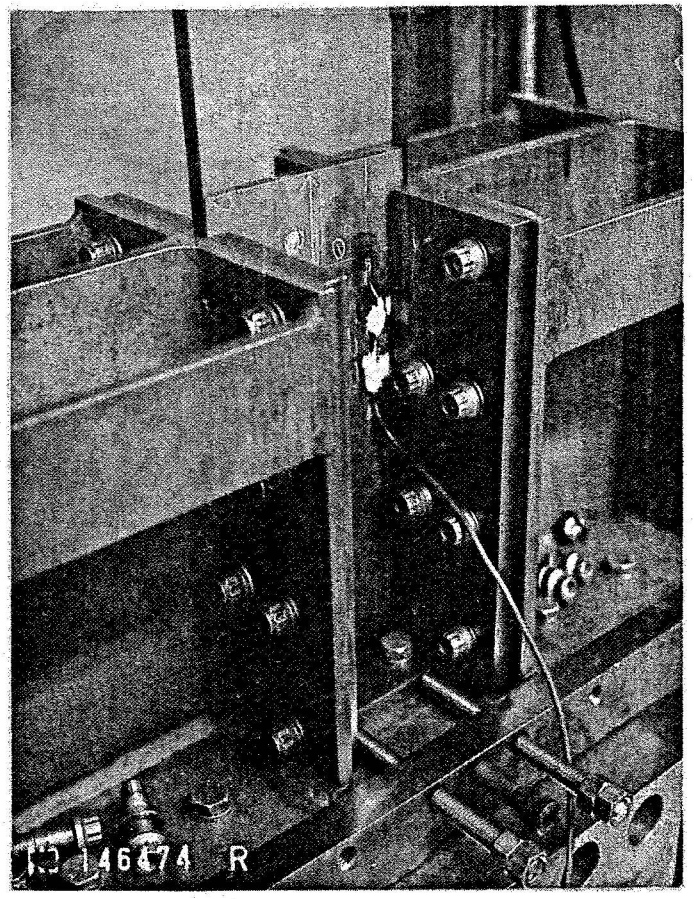


Figure 2-26: 5 x 12-Inch Compression Specimen Being Installed in Test Fixture. Shims are Installed Between Specimen Edges and Side Supports For Alignment.

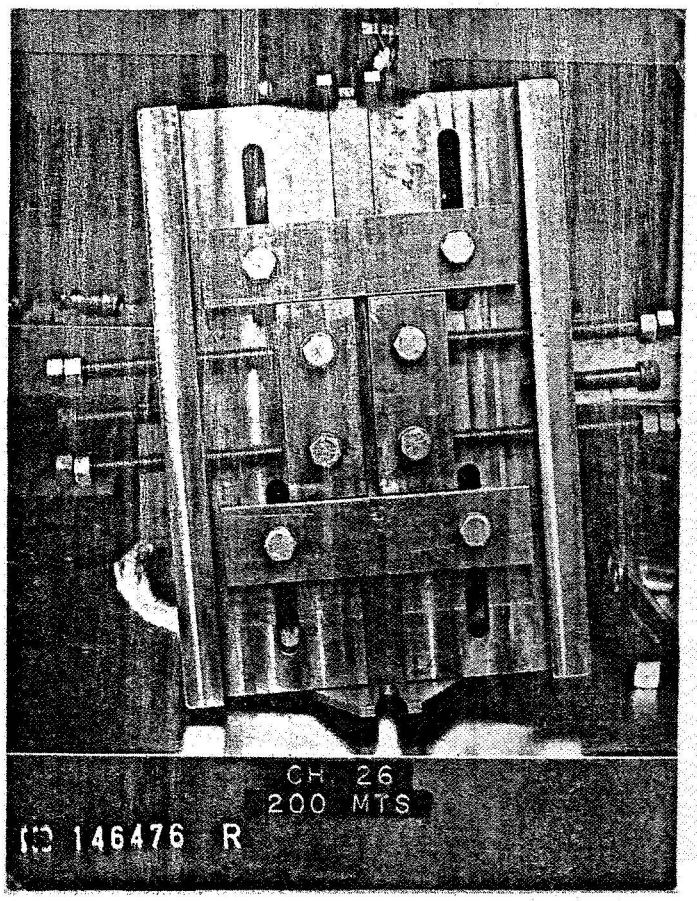


Figure 2-27: Top Loading Plate Showing End Restraint Details

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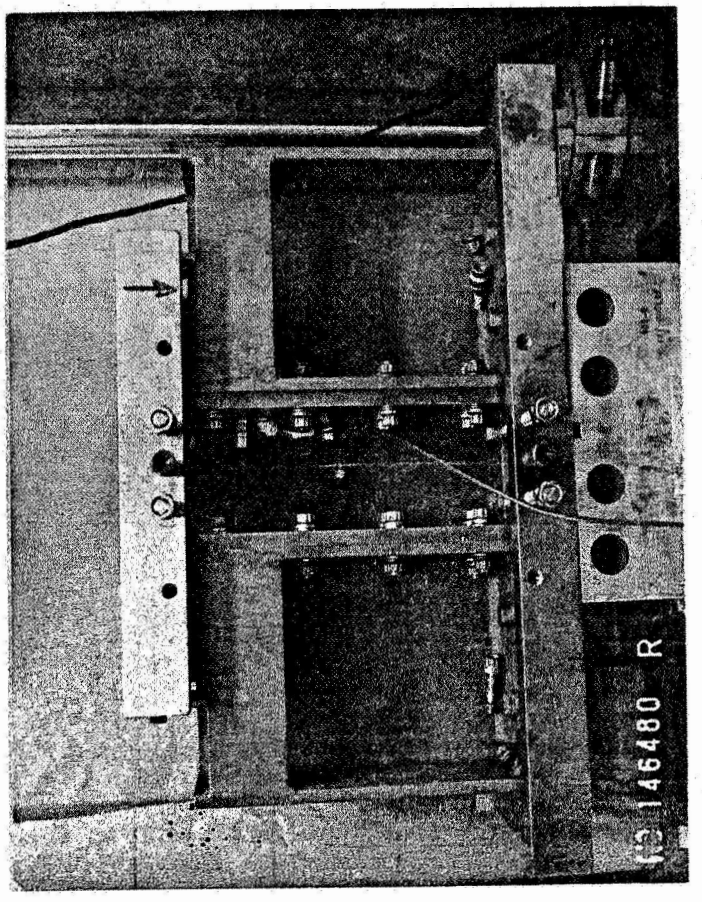


Figure 2-29: Front View Showing Specimen In Place

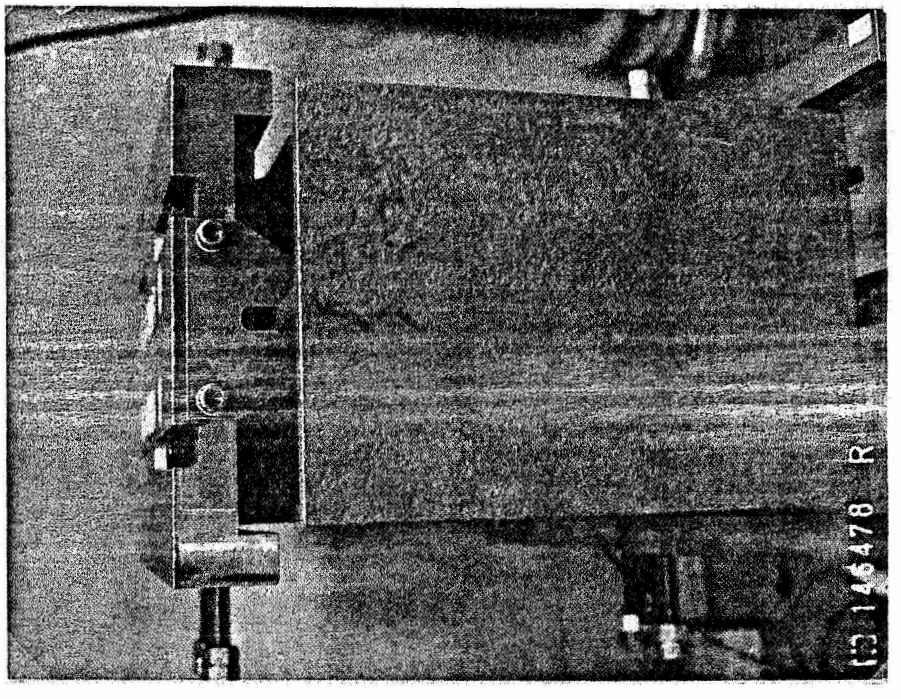


Figure 2-28: Top Plate Shown Installed On Side Supports

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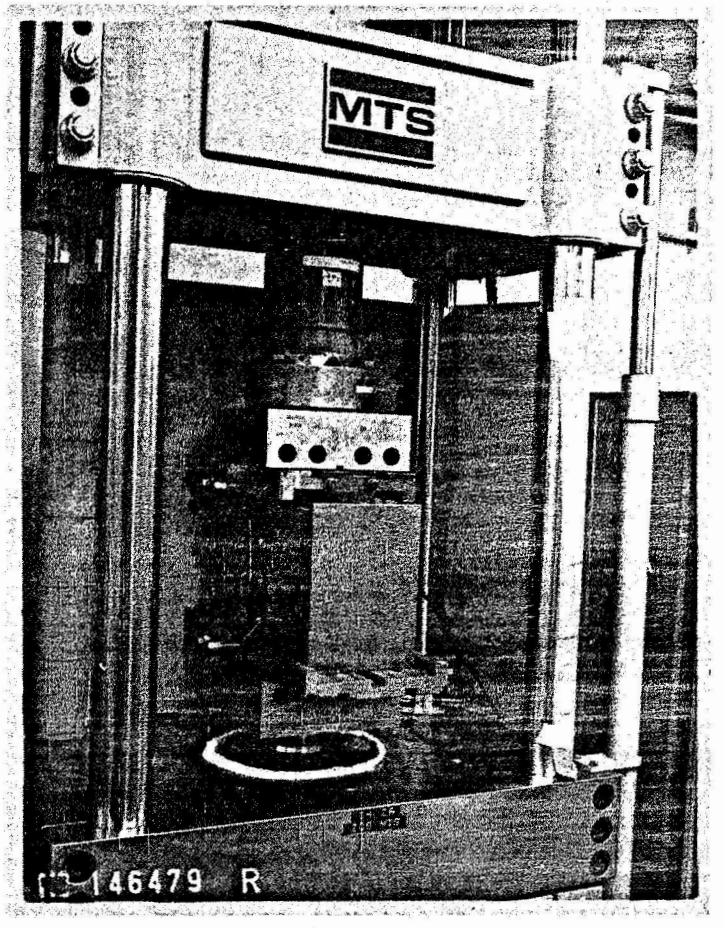


Figure 2-30: Compression Test Fixture Mounted For Test in 200 kip MTS Machine.

For tests at 180°,F hot air was ducted to each side of the specimen and contained by a custom fitted chamber. Thermocouples were mounted on the specimen and allowed to stabilize prior to loading. Undamaged compression tests on 2-inch wide specimens were performed in a V-groove fixture described in Section 4.2.

Results of compression tests on AS4/2220-1 are summarized in Table 2.5 and on Celion/982 in Table 2.6. Load-strain plots are presented in Appendix A-2. Specimens with 1-inch diameter holes all failed in compression through the holes in the width direction as shown typically in Figure 2-31. Also in Figure 2-31 is a closeup view of the specimen edge showing a typical mode. Impacted specimens also failed through the impact zone in the width direction as seen in Figure 2-32. Two inch wide specimens tested in the V-groove fixture failed catastrophically with multiple delaminations as shown in Figure 2-33, 2-34, and 2-35. Specimen 2-5-13B2 emitted a loud bang at 40970 pounds and was unloaded, but inspection revealed no failure. It was reloaded and finally failed catastrophically at 43760 pounds. Data for these tests are contained in Tables 2.5 and 2.6 and Appendix A-2.

2.4 INPLANE TENSION TESTS

Inplane tension test specimens were removed in the 0° longitudinal direction from the same AS4/2220 and Celion/982 panels as the compression panels in the preceeding section They were machined to the 2 x 14-inch geometry shown in Figure 2-36. All specimens had a 0.25-inch diameter hole with a single axial strain gage located on the longitudinal centerline 2-inches from the hole. Specimens did not have bonded tabs but when placed in hydraulic grips for testings and were separated from the serrated steel hydraulic grip pads by 0.06-inch thick lexan sheet tabs 2 x 3 inch on each side. This prevented damage to the graphite/epoxy specimen by the serrations and yet carried sufficient frictional load. Hydraulic grip

TABLE 2.5. AS4/2220-1 COMPRESSION TEST DATA

Laminate Orientation: $(45^{o}/0^{o}/135^{o}/90^{o})6S$
Laminate Resin Content: 34.32% by Weight

Coupon ID	Test Type and Cond.	Thickness (in.)	Width Weight (in.)	Impact Area ($in.^2$) or Hole Area (in.)	Failure (1) Load (kips)	Failure Stress (ksi)	Failure (2) Strain (μin./in.)	Modulus (msi)
2-2-12B	Open Hole	0.256	5.000	1.000	-39.94	-31.20	- 4720	6.56
2-3-12A	at $75^{o}F$	0.255	5.000	0.998	-40.78	-31.98	- 4800	6.75
2-3-12B	Dry	0.257	5.000	0.997	-38.65	-30.08	- 4620	6.61
Avg.	-	-	-	-	-39.79	-31.09	- 4713	6.64
2-1-12A	Open Hole	0.259	5.002	0.994	-32.08	-24.76	- 3720	6.96
2-1-12B	at $180^{o}F$	0.257	5.001	1.010	-32.34	-25.16	- 3740	7.15
2-2-12A	Wet (3)	0.260	5.002	0.997	-32.15	-24.72	- 3640	7.17
Avg.	-	-	-	-	-32.19	-24.89	- 3700	7.09
2-4-12A	20 ft. - lb.	0.255	5.001	1.81	-35.71	-28.00	- 4160	6.90
2-4-12B	Impact at	0.259	5.000	2.02	-32.70	-25.25	- 3930	6.64
2-5-12A	$75^{o}F$ Dry	0.255	4.963	1.99	-32.96	-26.04	- 4060	6.80
Avg.	-	-	-	-	-33.79	-26.43	- 4050	6.78
2-5-12B1	Unnotched (4)	0.256	2.001	-	-39.78	-77.66	-12905	6.80
2-5-12B2	at $75^{o}F$ Dry	0.257	2.006	-	-44.46	-86.14	-14710	6.96
Avg.	-	-	-	-	-42.12	-81.90	-13808	6.88

(1) All coupons failed at hole or damaged area
(2) Average of back-to-back gage data
(3) Wet = 45 days in H_2O @ $160^{o}F$ - Avg. weight gain = 0.89%
(4) V-groove compression fixture

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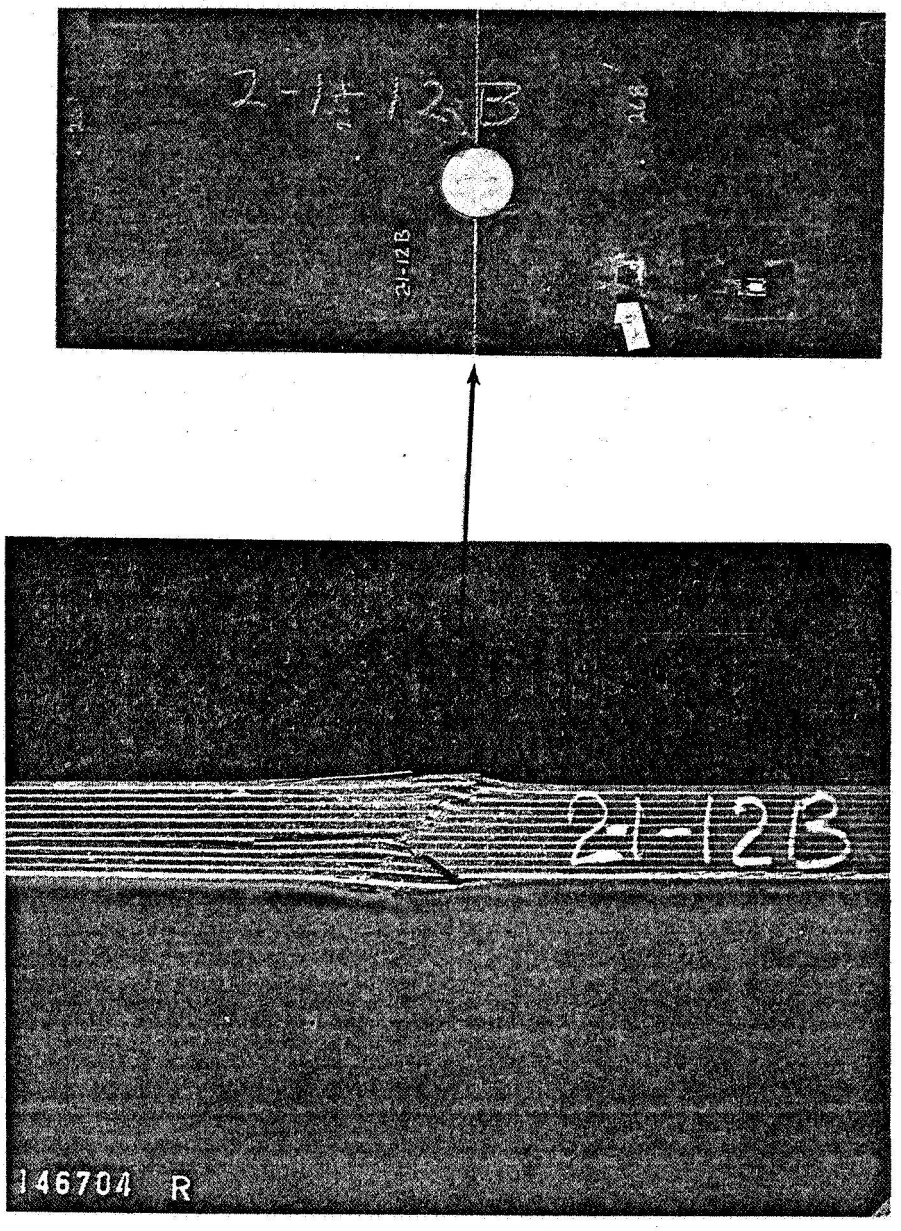


Figure 2-31: Typical Failure of 1" Diameter Notched Compression Specimen. In Top View Failure Is Across the Width Through the Hole. The Bottom View is a Close-Up of the Specimen Edge.

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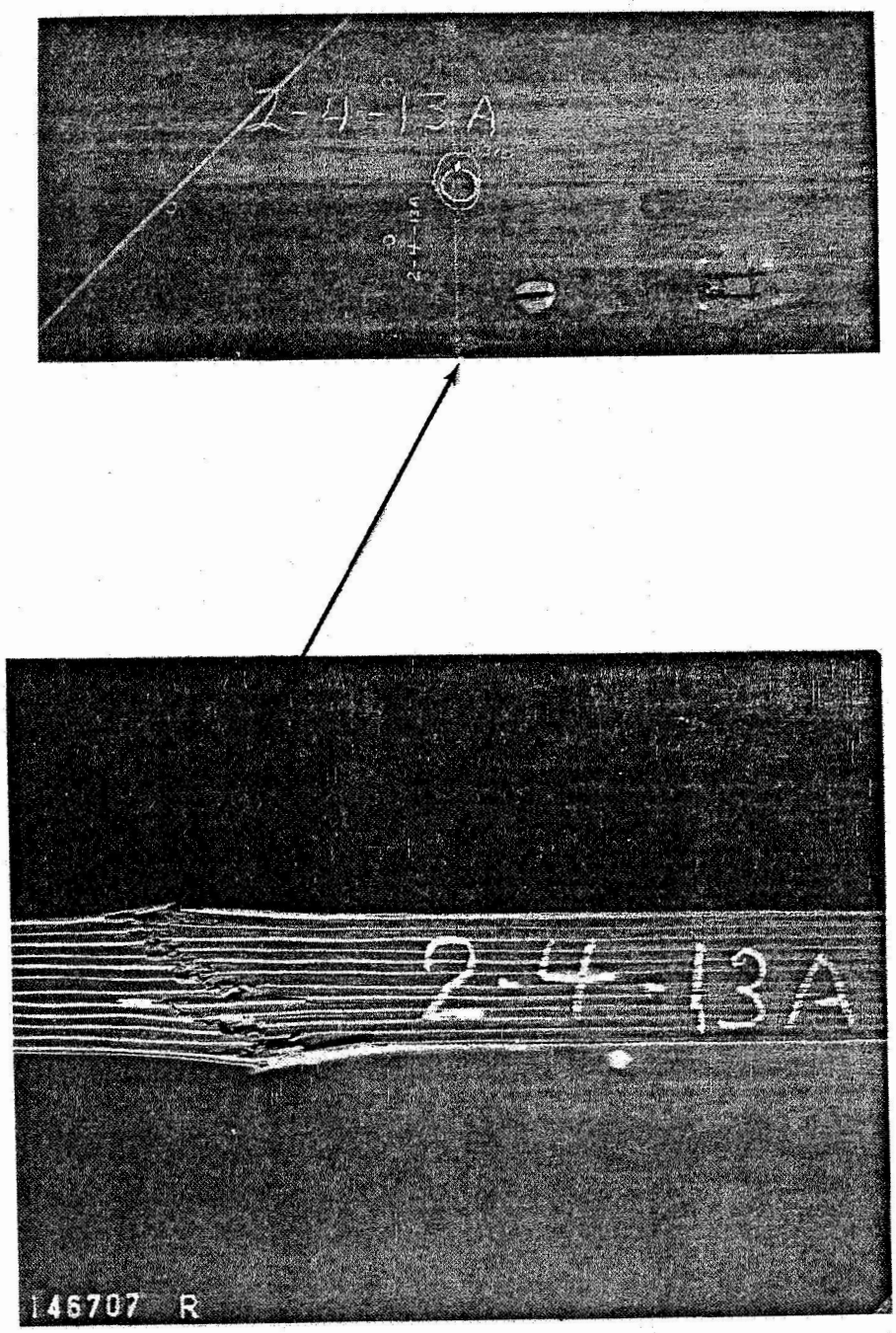


Figure 2-32: Typical Failure of an Impacted Compression Specimen. Failure is Through the Center of the Impact. The Bottom Photo Shows a Close-up of the Specimen Edge in the Failure Zone.

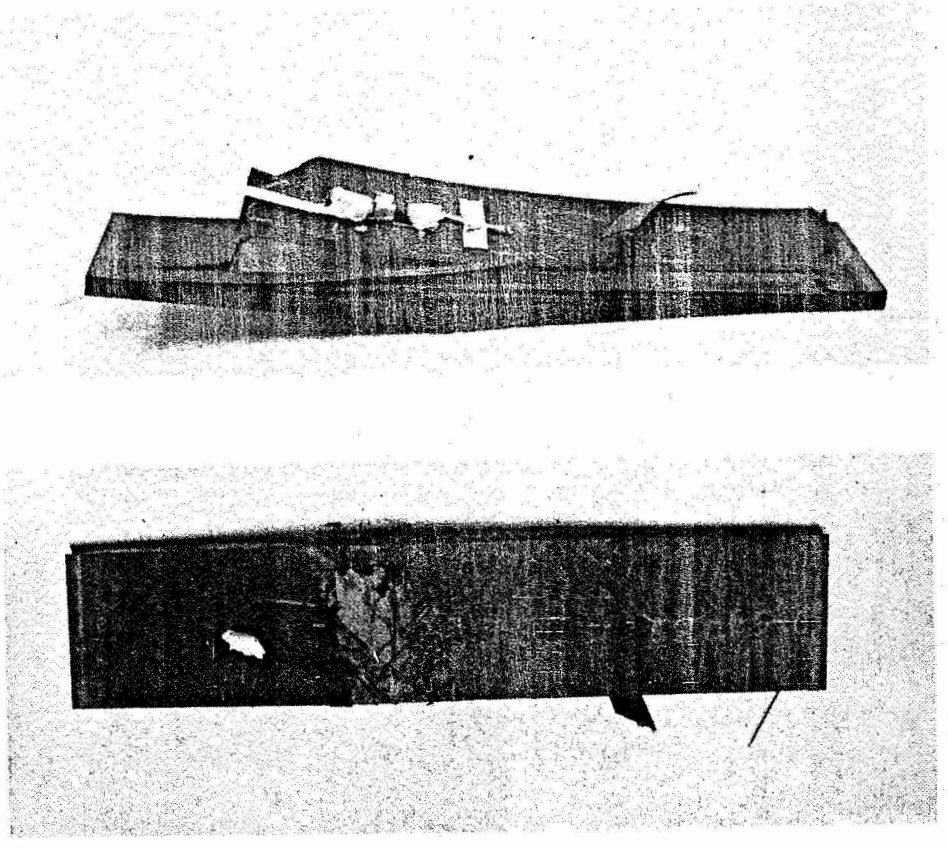


Figure 2-33: Compression Failure of Specimen 2-5-12B2 Tested in the 2-Inch Wide V-Groove Fixture.

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Figure 2-35: Compression Failure Of Specimen 2-5-13B1 Tested in the 2-Inch Wide V-Groove Fixture.

Figure 2-34: Compression Failure of Specimen 2-5-13B2 Tested in the 2-Inch Wide V-groove Fixture

TABLE 2.6. CELION/982 COMPRESSION TEST DATA

Laminate Orientation: $(45^{o}/0^{o}/135^{o}/90^{o})6S$

Laminate Resin Content: 36.33% by Weight

Coupon ID	Test Type and Cond.	Thickness (in.)	Width (in.)	Impact Area ($in.^2$) or Hole Dia. (in.)	Failure Load (kips) ①	Failure Stress (ksi)	Failure Strain (μin./in.) ②	Modulus (msi)
2-2-13B	Open Hole	0.303	5.001	1.000	-44.13	-29.12	- 4750	6.34
2-3-13A	at 75°F	0.307	5.000	0.998	-46.09	-30.03	- 4950	6.43
2-3-13B	Dry	0.306	5.000	0.999	-49.16	-32.13	- 5180	6.21
Avg.	-	-	-	-	-46.46	-30.43	- 4960	6.33
2-1-13A	Open Hole	0.303	5.001	0.998	-34.92	-23.04	- 3410	7.04
2-1-13B	at 180°F	0.306	5.001	0.997	-34.20	-22.35	- 3510	7.14
2-2-13A	Wet ③	0.309	5.001	0.998	-34.64	-22.42	- 3710	6.29
Avg.	-	-		-	-34.59	-22.60	- 3543	6.82
2-4-13A	20 ft-lb.	0.309	5.000	2.61	-50.74	-32.84	- 5480	6.04
2-4-13B	Impact at	0.308	4.995	2.94	-49.78	-32.36	- 5410	6.01
2-5-13A	75°F Dry	0.304	5.000	1.82	-45.37	-29.85	- 4880	6.18
Avg.	-	-	-	-	-48.63	-31.68	- 5257	6.08
2-5-13B	Unnotched ④	0.302	2.001	-	-47.86	-79.12	-14005	6.77
2-5-13B	at 75°F Dry	0.306	2.004	-	-43.76	-71.45	-11375	6.82
Avg.	-	-	-	-	-45.81	-75.29	-12690	6.79

① All coupons failed at hole or damaged area
② Average of back-to-back gage data
③ Wet = 45 days in H_2O @ 160°F - Avg. weight gain = 1.11%
④ V-groove compression fixture

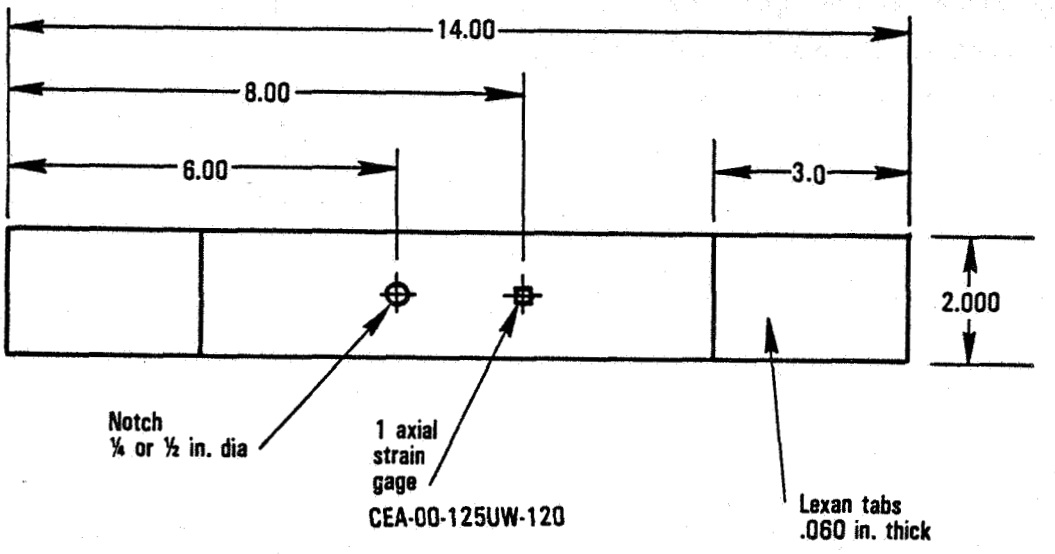


Figure 2-36: Inplane Tension Specimen Geometry

pressure was 2800 psi, which for this laminate produced no crushing. Depending on the particular laminate grip, pressure has to be carefully controlled so as not to damage the laminate and yet be sufficiently high to carry the tensile loads in friction. of several plastics evaluated, Lexan has shown to be the best material for this type of tabbing. Sufficient deformation occurs in the Lexan so that it conforms to the peel ply textured surface of the specimens and does not readily slip. Three and one-half-inch wide MTS hydraulic grips were used as shown in Figure 2-37 and 2-38. All specimens failed through the 0.25-inch diameter holes. Loading rate was at 0.05-inch/minute. Data for these tests are summarized in Table 2.7. Stress strain curves are contained in Appendix A-3.

2.5 INTERLAMINAR TENSION TESTS

Blocks 1.0 x 1.0-inch were cut from the same 48-ply panels of AS4/2220 and Celion/982 as the compression and tension tests described in the previous sections. These blocks were bonded to 1 x 1 x 1-inch aluminum blocks drilled and pinned to provide a universal joint on both ends of the specimen so that no bending loads could be applied across the specimen. These were then loaded in tension at a rate of 0.05-inch/minute to failure. Head deflection was plotted versus load and was a smooth curve up to failure.

Initially all specimens were bonded to the aluminum blocks with Hysol 151 epoxy and cured at room temperature for 24 hours. The first two specimens tested failed in the Hysol bond at 1510 and 1634 lbs. Since additional unbonded specimens were not available, the bonded ones had to be removed from the aluminum blocks. Soaking them in CO_2 at approximately -90°F and tapping transversely on the blocks with a small hammer proved ineffective. Next a razor blade used as a chisel was tried. Generally this worked well, but in some cases alignment of the blade to the bond line was not sufficiently accurate and some specimens were damaged beyond salvage. Rebonding with Goodrich A1273 and room temperature curing was then tried, but failure

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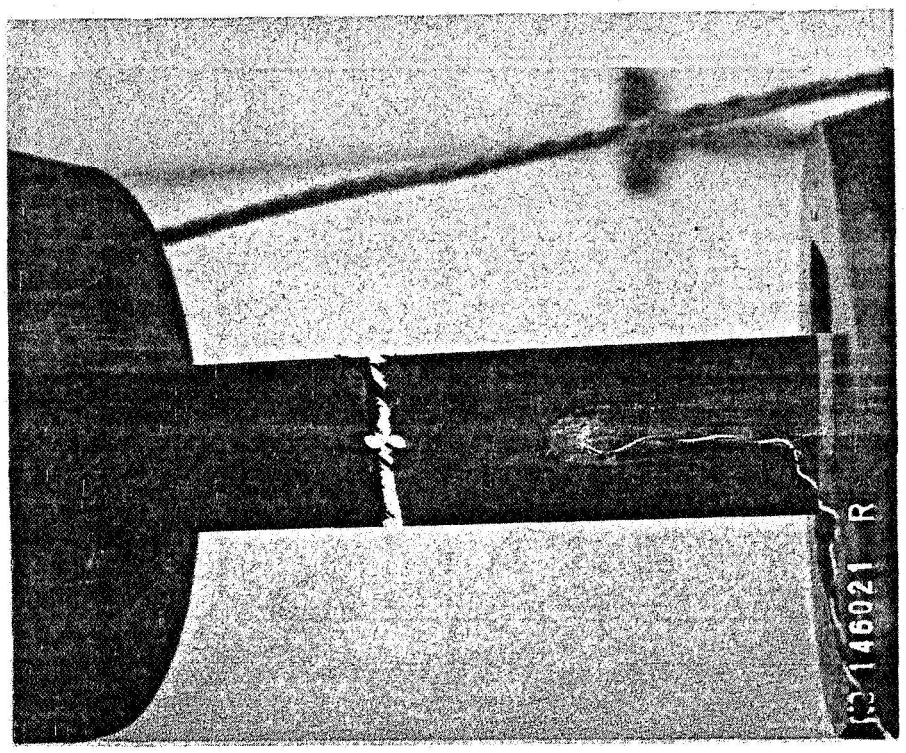


Figure 2-38: Typical Notched Tensile Failure

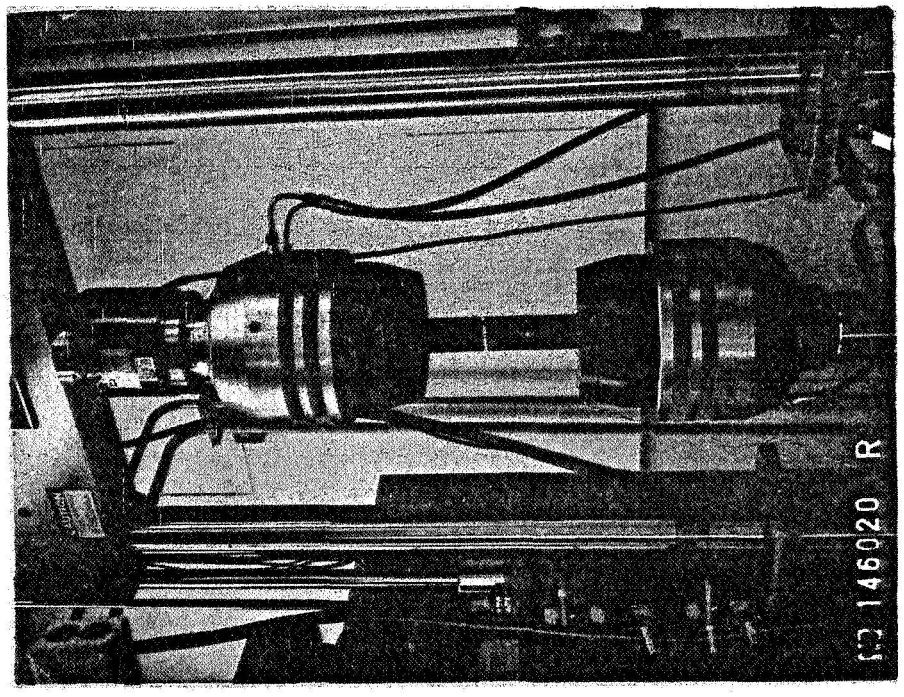


Figure 2-37: Notched Tensile Test Specimen Mounted in Hydraulic Grips

TABLE 2.7 NOTCHED TENSILE TEST DATA ①

	Specimen ID	Width (in.)	Thickness (in.)	Area (in.)	Failure Load (lb.)	Failure Stress (psi)	Failure Strain (μ in./in)
AS4/2220	12-1	1.996	.2592	.5174	25,810	49,890	6,778
	12-2	1.997	.2570	.5132	24,930	48,570	6,474
	12-3	1.999	.2564	.5125	25,280	49,340	6,918
	Avg.				25,340	49,267	6,723
Celion/982	13-1	2.000	.2978	.5956	28,840	48,420	6,647
	13-2	2.000	.3065	.6130	28,740	46,890	6,530
	13-3	2.000	.3065	.6130	29,390	47,940	6,313
	Avg.				28,990	47,750	6,497

① 0.25 in. diameter hole

occurred at 1600 lbs. All remaining specimens were cleaned and rebonded with FM137 and cured at 250°F. With this adhesive, failures did occur in the laminate at over 3000 lbs. as summarized in Table 2.8. Due to the bonding and removal difficulties insufficient numbers of valid data points were obtained, particularly at -65°F, to draw conclusions on the relative interlaminar tensile strengths of the two materials. Figure 2-39 shows several of the failures. The light stripe in specimen 13-3 is a Kevlar strip used for fiber orientation verification, other specimens had these but did not fail on that particular lammina plane.

2.6 CONDITIONING WEIGHT GAIN SPECIMENS

AS4/2220 and Celion/982 specimens 1 x 1 inch by 48-plies thick were immersed in water at 160°F for 7 weeks. Specimens were weighed once each week. Weight values and percent change are listed in Tables 2.9 and 2.10, and presented graphically in Figure 2-40.

A similar group of both laminates was placed in Jet-A fuel at 70 $\pm$ 5°F for 7 weeks and weighed weekly. This weight and percent weight change data are presented in Tables 2.11 and 2.12, and graphically in Figure 2-41.

Celion/982 in 160°F water increased in weight by 1.11% and in Jet-A by 0.118%. AS4/2220 absorbed considerably less of either water or fuel than the Celion/982, increasing by 0.89% in water and 0.074% in fuel.

Data scatter in the Jet-A is much larager than in the water for both laminates. Weighing techniques for the Jet-A specimens were the same for all measurements and by the same person except for week 5, when weighings by another person deviated so widely from the other data that they could not be considered valid. The original weight listed is that of specimens dipped in the fuel for 5 minutes prior to the initial weighing to correct for surface wetting which is not absorbed weight.

TABLE 2.8: INTERLAMINAR TENSION TESTS

Specimen ID	Material	Area $in.^2$	Temp ^oF	Max. Load lbs	Grip Adhesive	Remarks
12-1	AS4/2220	1.0	75	1510	Hysol 151	Failed in grip bond
12-2	↓	↓	↓	1634	Hysol 152	Failed in grip bond
12-1				1600	Goodrich A1273	Failed in grip bond
12-2				3000	FM 137	
12-3				3015	FM 137	
13-1	Celion/982			3025	FM 137	
13-2	↓			2915	FM 137	
13-3			↓	2680	FM 137	
12-5	AS4/2220		-65	2295	FM 137	
13-4	Celion/982			2350	FM 137	
13-6	Celion/982	↓	↓	500	FM 137	Failed at rebond damage site

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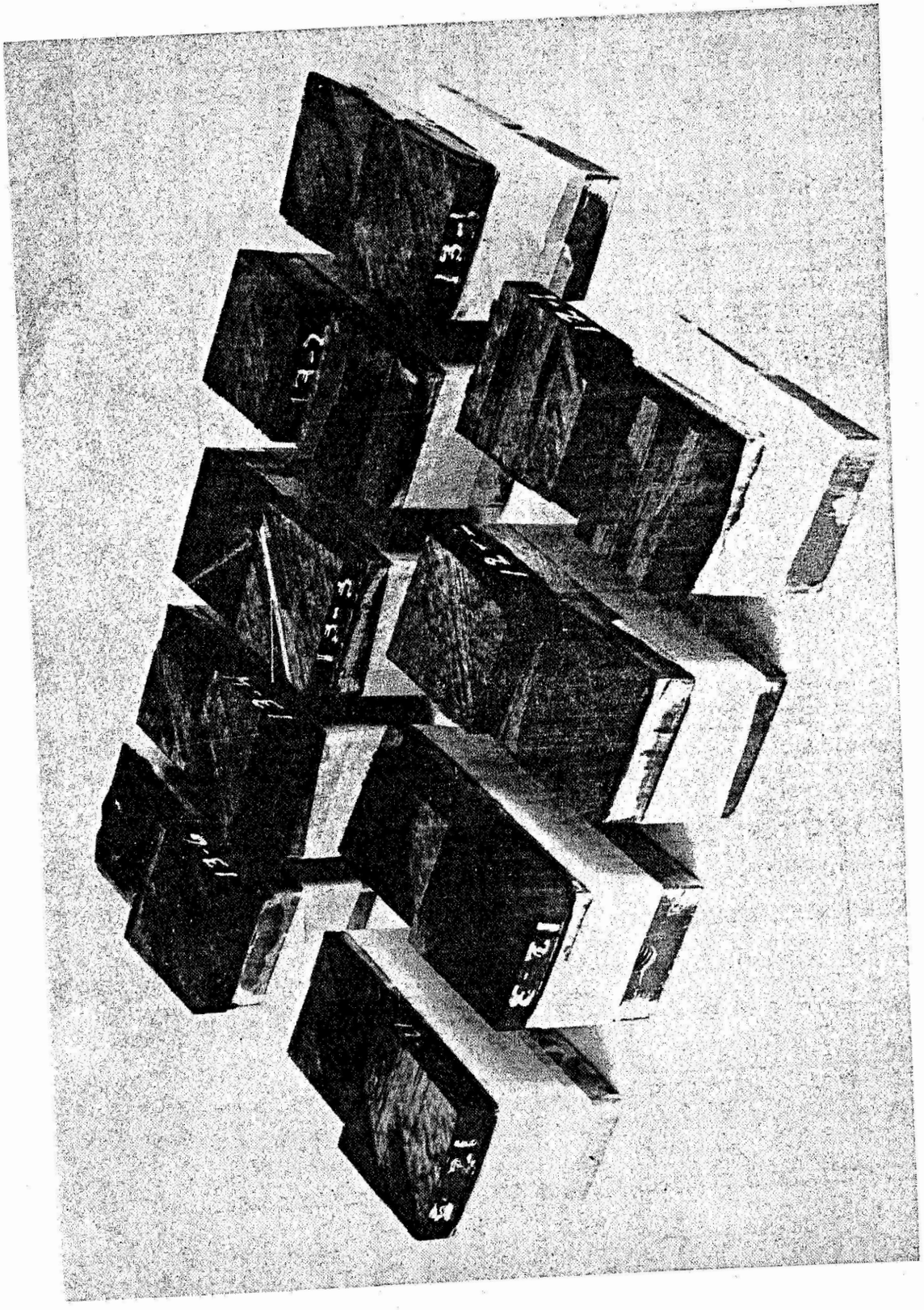


Figure 2-39: Failures of Interlaminar Tensile Test Coupons

TABLE 2.9 : AS4/2220 Weight Gain in 160°F Water Immersion

	Spec. ID	Original	Weeks 1	2	3	4	5	6	7
Weight gms.	12-1	6.5724	6.6036	6.6215	6.6322	6.6229	6.6434	6.6320	6.6351
	12-2	6.7099	6.7442	6.7516	6.7611	6.7613	6.7745	6.7674	6.7692
	12-3	6.6718	6.7036	6.7116	6.7238	6.7203	6.7315	6.7250	6.7278
% Change	12-1	-	.47	.75	.91	.76	1.08	.91	.95
	12-2	-	.51	.62	.76	.77	.96	.86	.88
	12-3	-	.48	.60	.78	.73	.89	.80	.84
	Avg.		.49	.66	.82	.75	.98	.86	.89

TABLE2.10 : Celion/982 Weight Gain in 160°F Water Immersion

	Spec. ID	Original	Weeks 1	2	3	4	5	6	7
Weight gms.	13-1	7.6768	7.7207	7.7343	7.7441	7.7496	7.7579	7.7590	7.7626
	13-2	7.6431	7.6859	7.6981	7.7082	7.7135	7.7207	7.7228	7.7259
	13-3	7.7429	7.7876	7.8008	7.8116	7.8168	7.8266	7.8267	7.8301
% Change	13-1	-	.57	.75	.88	.95	1.05	1.07	1.12
	13-2	-	.56	.72	.67	.92	1.02	1.04	1.08
	13-3	-	.58	.75	.89	.93	1.08	1.08	1.13
	Avg.		.57	.74	.81	.93	1.05	1.06	1.11

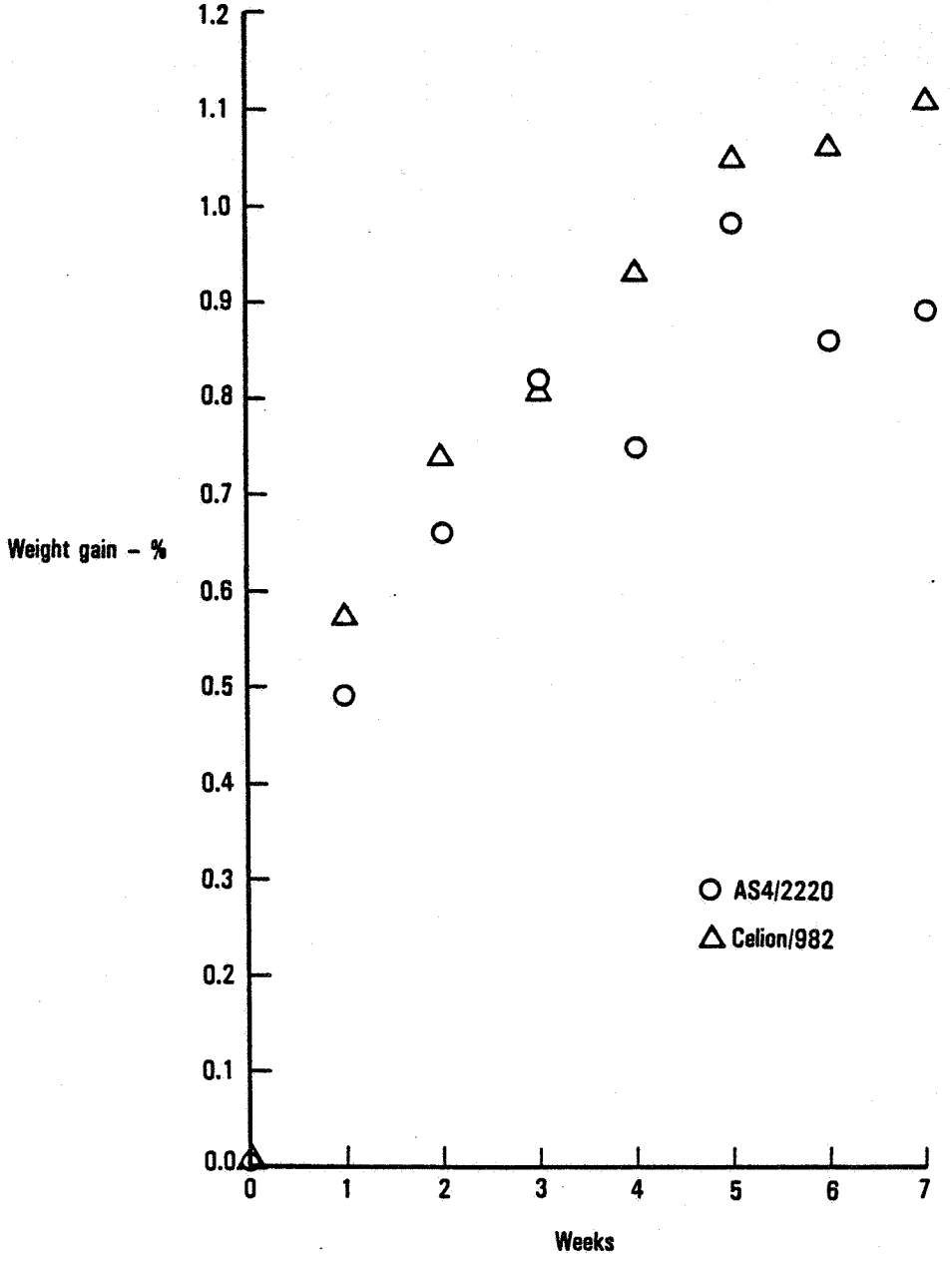


Figure 2-40: Weight Gain in 160°F Water Immersion

TABLE 2.11: AS4/2220 Weight Gain In Jet-A Fuel

	Spec. ID	Original	Weeks 1	2	3	4	5	6	7
Weight gms	12-1	6.6332	6.6340	6.6371	6.6366	6.6381	-	6.6380	6.6381
	12-2	6.6171	6.6252	6.6227	6.6229	6.6232	-	6.6190	6.6236
	12-3	6.6782	6.6791	6.6796	6.6798	6.6799	-	6.6824	6.6816
% Change	12-1	-	.012	.059	.051	.074	-	.072	.074
	12-2	-	.122	.085	.088	.092	-	.029	.098
	12-3	-	.013	.021	.024	.025	-	.063	.051
	Avg.		.049	.055	.054	.064		.055	.074

TABLE 2.12: Celion/982 Weight Gain in Jet-A Fuel

	Spec. ID	Original	Weeks 1	2	3	4	5	6	7
Weight gms	13-1	7.8074	7.8140	7.8179	7.8157	7.8161	-	7.8184	7.8168
	13-2	7.7867	7.7916	7.7941	7.7932	7.7932	-	7.7966	7.7957
	13-3	7.8038	7.8094	7.8109	7.8106	7.8117	-	7.8137	7.8129
% Change	13-1	-	.085	.134	.106	.111	-	.141	.120
	13-2	-	.063	.095	.083	.104	-	.127	.116
	13-3	-	.072	.091	.087	.106	-	.126	.117
	Avg.		.073	.107	.092	.107	-	.131	.118

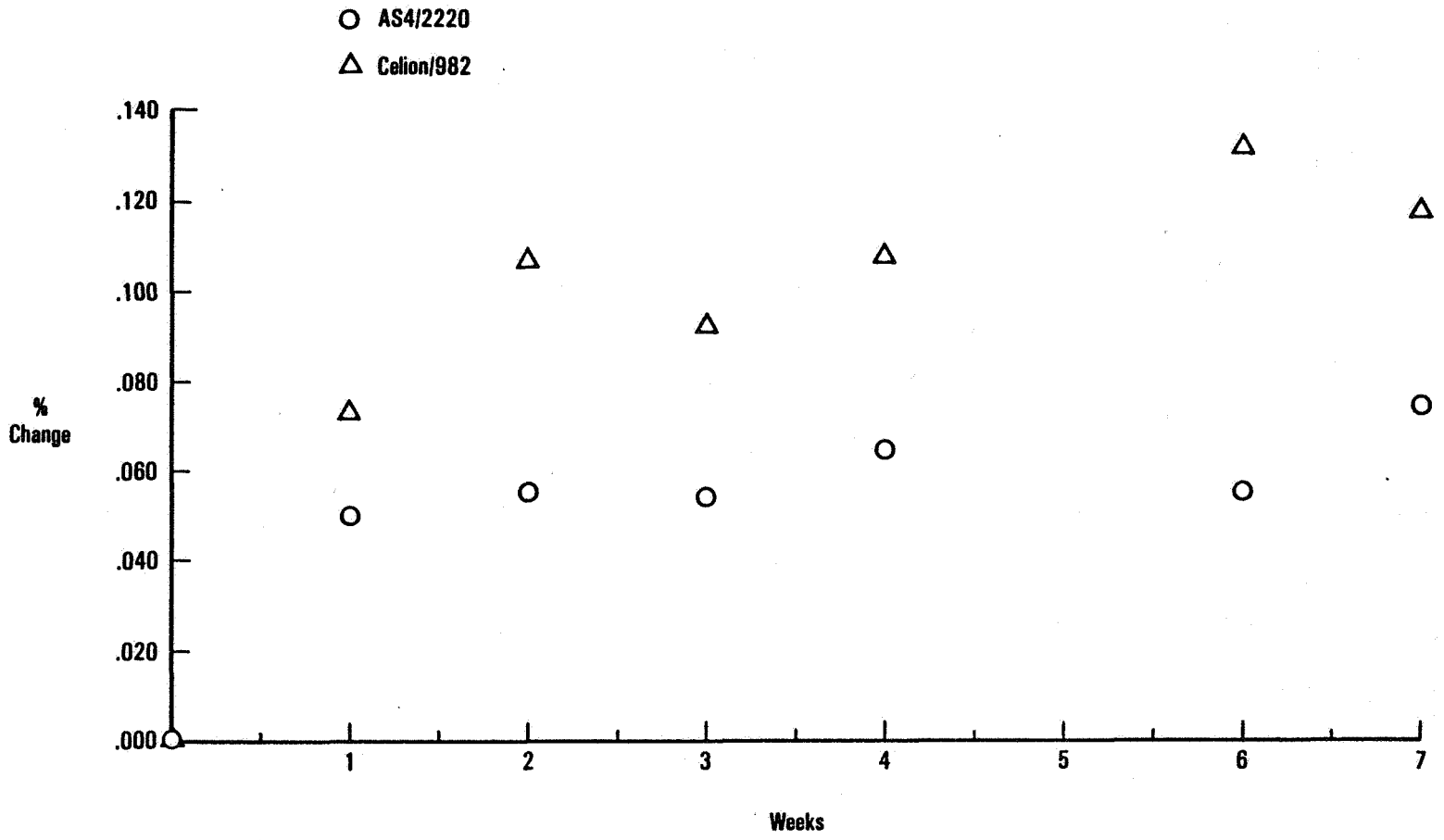


Figure 2-41: Weight Gain in Jet-A Fuel

SECTION 3
SURFACE PREPARATION AND FUEL CONTAINMENT

3.1 SURFACE PREPARATION TESTS

3.1.1 Laminate Fabrication

The effect of laminate surface condition and adhesion was studied on specimens cut from a quasi-isotropic AS4/3502 laminate and fabricated with different mold-release techniques in conjunction with different surface preparation methods. This effort is part of a study to evaluate fuel tank sealing in substructure to cover joints.

To provide the test specimens, a 24-ply, quasi-isotropic panel of Hercules AS4/3502, 24 in. x 38 in. with an orientation of $(\pm 45^{\circ}/0^{\circ}/90^{\circ})_{3S}$, was fabricated. One side of the laminate was cured against a nylon peel ply and the other side against a silicone rubber sheet.

Surface evaluation specimens consisted of lap shear coupons (see Figure 3.1), 1 in. x 9.5 in. with 0.5 in. lap, bonded with AF-10 nitrile phenolic adhesive film and tested per ASTM D1002. In addition, 180° peel specimens were prepared per the method described in MIL-S-8802E Par. 4.8.17 (no fluid immersion) using wire screen enmeshed in PR1422 sealant.

Two coats of MIL-C-27725 (thermally cured polyurethane fuel tank coating) were applied to the faying surfaces of one-half of the lap shear coupons. Each coat was 0.8 - 1.5 mils thick. A thin coat of EC1290 adhesive primer was applied to the faying surfaces of all lap shear coupons.

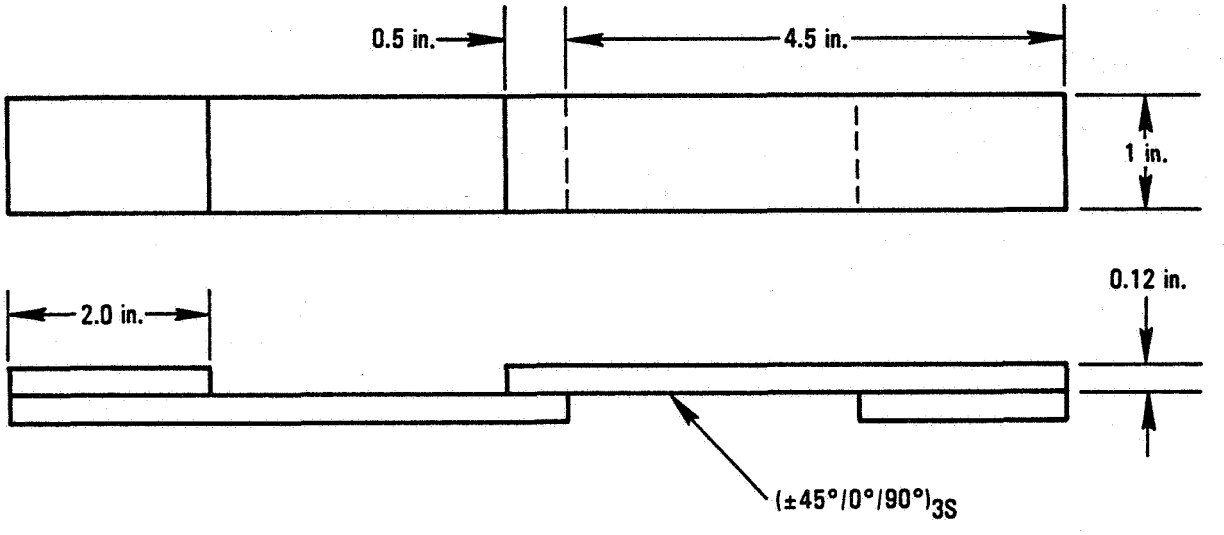


Figure 3-1: Lap Shear Test Specimen With Bonded Fiberglass Tabs.

Lap shear coupons were divided into three groups: 1) cured against peel ply and wiped with methyl ethyl ketone (MEK) prior to application of any faying surface treatment; 2) cured against silicone rubber sheet and wiped with 1,1,1 - trichloroethane; and 3) cured against silicone rubber sheet and vapor honed with 180 grit abrasive.

To assist in gripping the lap shear specimens during tensile testing, fiberglass tabs, 0.12 in. thick, were bonded on one side to the ends of each lap shear specimen using EA9309 adhesive. The bonded tab configuration is shown in Figure 3.1.

180° peel specimens, with wire screen enmeshed in PR1422 2-part, chromate cured polysulfide sealant, were prepared by application of the same selection of surface preparations as with the lap shear specimens. The configuration of the 180° peel test specimens is shown in Figure 3.2.

An overview of the test program for surface evaluation is given in Table 3-1.

The 24 in. x 38 in. AS4/3502 24-ply panel from which the surface evaluation specimens were made showed no defects upon ultrasonic non-destructive inspection by C-scan. The resin content (average of 3 determinations) was 32.3%. The average thickness was 0.137 in., corresponding to an average thickness of 5.7 mils per ply. The measured value for interlaminar tension (average of 3 values) was 1527 psi.

3.1.2 Lap Shear Tests

The lap shear data on specimens made from the surface evaluation panel are shown in Table 3.2. The lap shear specimen failure surfaces are shown in Figures 3-3 through 3-8. As seen in Figure 3-3 failure included shear/tensile rupture of the laminate and little adhesive failure. This combination produced the highest strength of all methods evaluated. Adding

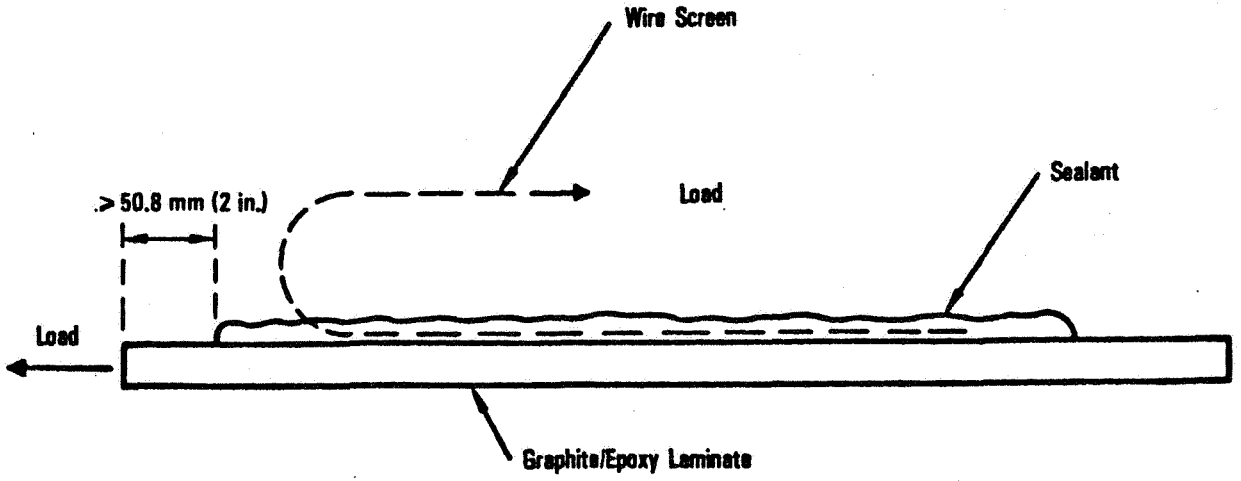


Figure 3-2: -180° Peel Test Per MIL-S-8802E

TABLE 3.1 - SURFACE PREPARATION EVALUATION TEST MATRIX

Specimen Type	Specimen Size	Preparation Method	Number of Tests	Test Method and Conditions	Remarks
Adhesive Lap Shear Test (Primed with EC-1290, Bonded with AF-10)	25.4 mm (1 in.) x 241 mm (9.5 in) with 12.7 mm (0.5 in.) overlap	Composite Fab with Peel Ply	6	ASTM D 1002 Ambient Temperature	3 specimens of each method uncoated and 3 specimens of each type coated with MIL-C-27725 fuel tank coating prior to application of adhesive primer.
		Silicone bag Solvent Cleaned	6		
		Silicone bag Solvent Cleaned and Grit Blast	6		
Sealant 180° Peel Test	31.8 mm (1.25 in.) x 254 mm (10 in.) x 3.05 mm (0.12 in.)	Composite Fab with Peel Ply	6	MIL-S-8802E Ambient Temperature	
		Silicone bag Solvent Cleaned	6		
		Silicone bag Solvent Cleaned and Grit Blast	6		
		Total Tests	36		

TABLE 3.2 - AS4/3502 SURFACE PREPARATION LAP SHEAR TEST DATA [a]

Specimen I.D.	Surface	Faying Surface Treatment	F_{TU} MPa (psi)	F_{TU} (Ave.) MPa (psi)
1A-1	Peel Ply	MEK wipe	22.62 (3280)	
-2		MEK wipe	21.10 (3060)	22.17 (3216)
-3		MEK wipe	22.81 (3308)	
1B[b]-1	Peel Ply	MEK wipe	17.65 (2560)	
-2		MEK wipe	18.31 (2656)	18.09 (2624)
-3		MEK wipe	18.31 (2656)	
2A-1	Silicone Rubber	Trichlor [c] wipe	18.86 (2736)	
-2		Trichlor [c] wipe	18.06 (2620)	19.06 (2765)
-3		Trichlor [c] wipe	20.27 (2940)	
2B[b]-1	Silicone Rubber	Trichlor wipe	11.64 (1688)	
-2		Trichlor wipe	18.53 (2688)	14.64 (2124)
-3		Trichlor wipe	13.76 (1996)	
3A-1	Silicone Rubber	Vapor Hone	17.38 (2520)	
-2		Vapor Hone	18.48 (2680)	17.49 (2536)
-3		Vapor Hone	16.60 (2408)	
3B[b]-1	Silicone Rubber	Vapor Hone	13.93 (2020)	
-2		Vapor Hone	13.38 (1940)	13.40 (1943)
-3		Vapor Hone	12.88 (1868)	

(a) EC 1290 primer and AF10 adhesive were used in bonding all lap shear specimens.

(b) Two coats of MIL-C-27725 fuel tank coating applied to faying surfaces.

(c) 1, 1, 1-trichloroethane.

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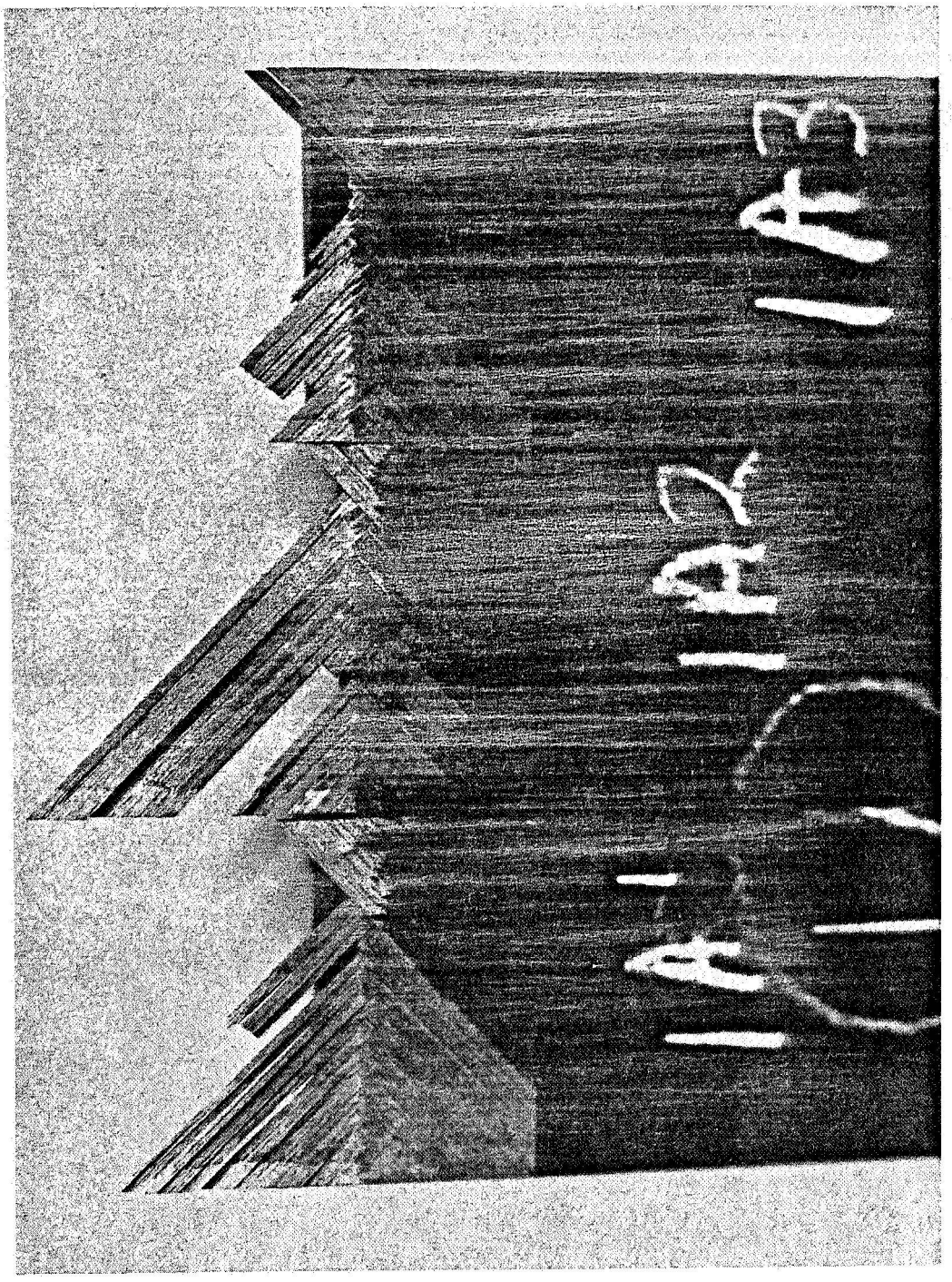


Figure 3-3: Lap Shear Specimen Failure on MEK Wiped Peel Ply Surface.

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Figure 3-4: Lap Shear Specimen Failures on MEK Wiped Peel Ply Surfaces with MIL-C-27725 Fuel Tank Coating.

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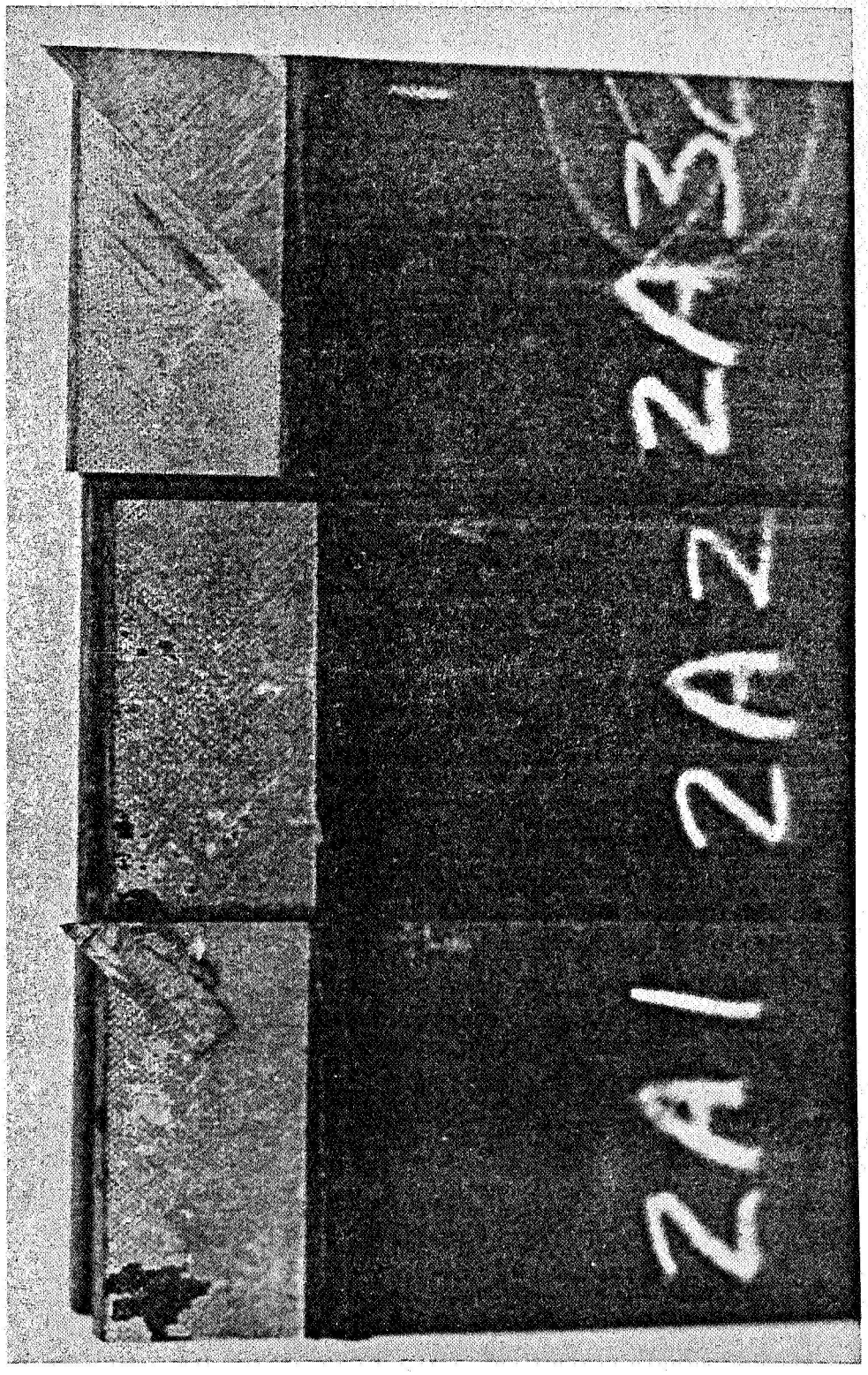


Figure 3-5: Lap Shear Specimen Failures on Trichlor Wiped Silicone Rubber Surfaces.

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Figure 3-6: Lap Shear Specimen Failures on Trichlor Wiped Silicone Rubber Surfaces with MIL-C-27725 Fuel Tank Coating.

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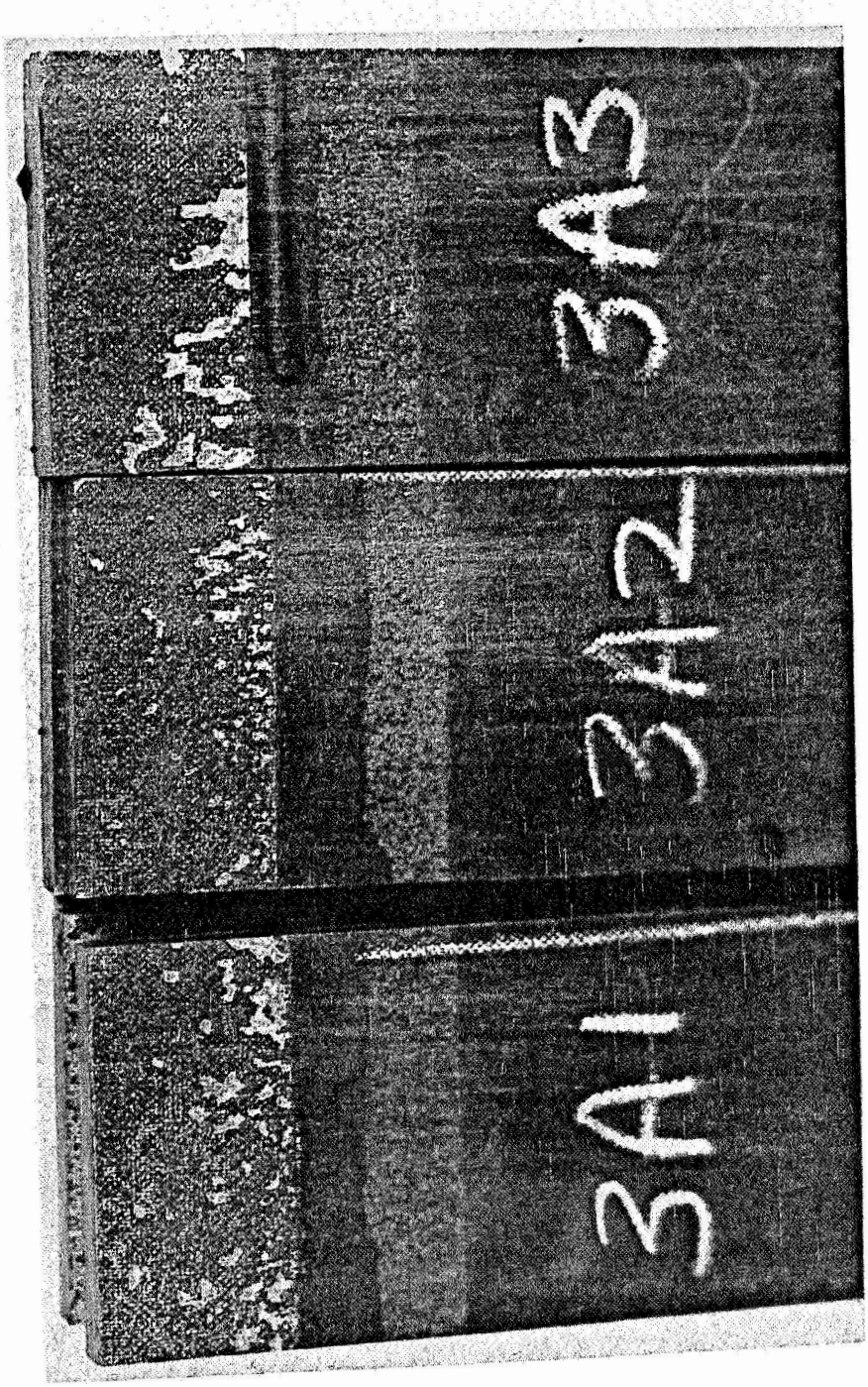
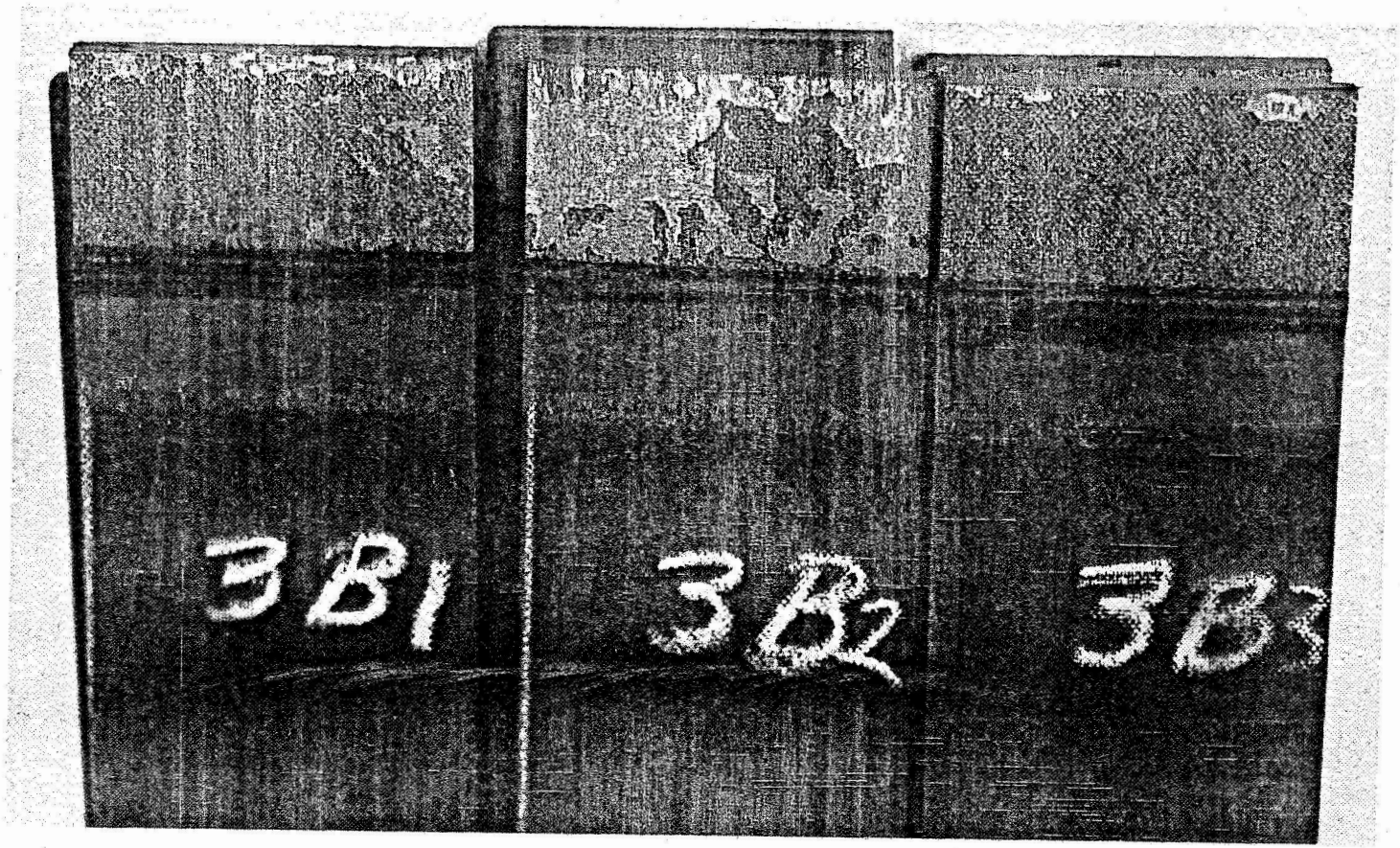


Figure 3-7: Lap Shear Specimen Failures on Vapor Honed Silicone Rubber Surfaces.



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Figure 3-8: Lap Shear Specimen Failures on Vapor Honed Silicone Rubber Surfaces with MIL-C-27725 Fuel Tank Coating.

two coats of MIL-C-27725 fuel tank coating to the faying surfaces of the specimens resulted in failures shown in Figure 3-4. These had less shear/tensile laminate failure and more bond line failures than in Figure 3-3 and a concomitant reduction in strength (see Table 3.2).

Specimens with a trichlor (1,1,1-trichloroethane) wiped silicone rubber textured surface demonstrated a small amount of shear/tensile laminate failure but were mostly of a bond rupture type as shown in Fgiure 3-5. Figure 3-6 is the same type as Figure 3-5 but with MIL-C- 27725 fuel tank coating added to the failure surfaces. These had lower strength values (see Table 3.2) and were all of a bond rupture type failure.

Vapor honed silicone rubber textured surface failures are shown in Figure 3-7 and with fuel coating added in Figure 3-8. Both types produced bond rupture type failures. The data consistently show that the lap shear strength obtained from specimens bonded to the peel ply surface are higher than those obtained by bonding to the silicone rubber surface. Also apparent from the data is the degradation of the average lap shear bond strength in excess of 580 psi by application of the MIL-C-27725 fuel tank coating.

3.1.3 180° Peel Tests

Three panels were assembled with various surface treatments listed in Table 3.3. Once cured, one inch wide strips 1/4 in. apart were cut through the coating and screen to the laminate surface. Panels were mounted in a static test machine as shown in Figure 3-9. The panel is pin loaded on the bottom and supported on the opposite bottom corner to prevent off 0° axis loading. The bottom head remained fixed while the top grip holding the screen pulled vertically upward peeling the screen from the panel as shown in Figure 3-10. After the first strip on the left was peeled, the bottom pin was moved to the next hole to the right and strip 2 was peeled, and so on across the panel always maintaining longitudinal loading.

TABLE 3.3 180° SEALANT PEEL TESTS [a]

Specimen I.D.	Surface	Initial Peel Strength KPa	(psi)	Prior to 1st Cut KPa	(psi)	After 1st Cut KPa	(psi)	After 2nd Cut KPa	(psi)	After 3rd Cut KPa	(psi)
1 (b)	Peel Ply	172	(25)	110	(16)	90	(13)	76	(11)	76	(11)
2 (b)	↓	152	(22)	70	(10)	110	(16)	76	(11)	76	(11)
3 (b)(e)	↓	159	(23)	117	(17)	124	(18)	145	(21)	124	(18)
4 (b)(e)	↓	165	(24)	131	(19)	124	(18)	131	(19)	131	(19)
9 (c)	Silicone Rubber	41	(6)	41	(6)	28	(4)	21	(3)	21	(3)
10 (c)	↓	48	(7)	35	(5)	28	(4)	28	(4)	14	(2)
11 (c)(e)	↓	152	(22)	103	(15)	97	(14)	70	(10)	117	(17)
12 (c)(e)	↓	159	(23)	(f)							
5 (d)	↓	90	(13)	41	(6)	28	(4)	28	(4)	35	(5)
6 (d)	↓	48	(7)	41	(6)	21	(3)	28	(4)	35	(5)
7 (d)(e)	↓	152	(22)	(f)							
8 (d)(e)	↓	138	(20)	(f)							

(a) All specimens were prepared with wire screen enmeshed in PR-1422 sealant and tested per MIL-S-8802E Par. 4.8.1.7.
(b) MEK Surface Treatment.
(c) Surface cleaned with 1, 1, 1-trichloroethane
(d) Surface vapor honed
(e) MIL-C-27725 fuel tank coating applied to surface.
(f) Wire mesh broke during test.

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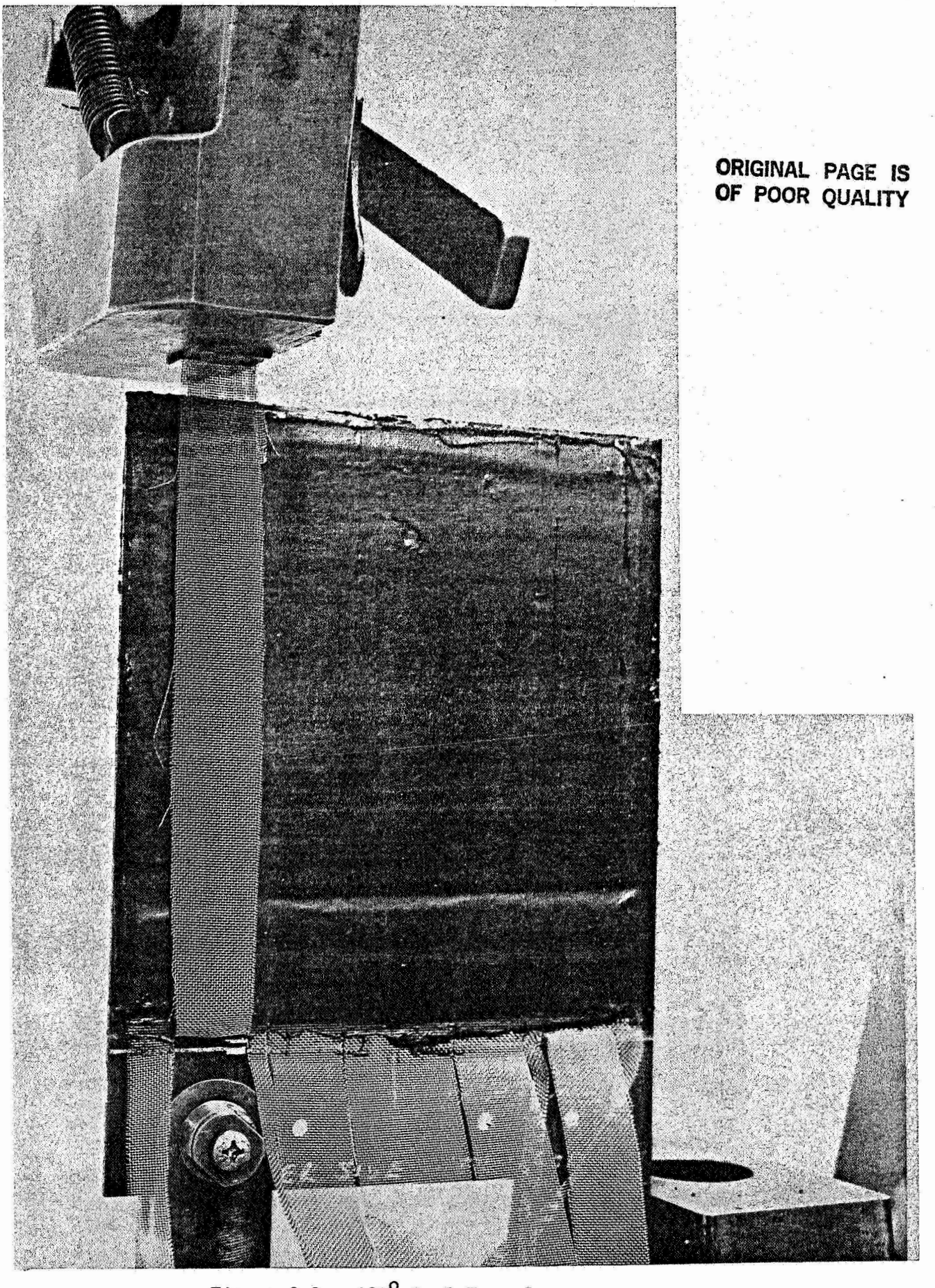


Figure 3-9: 180° Peel Test Setup

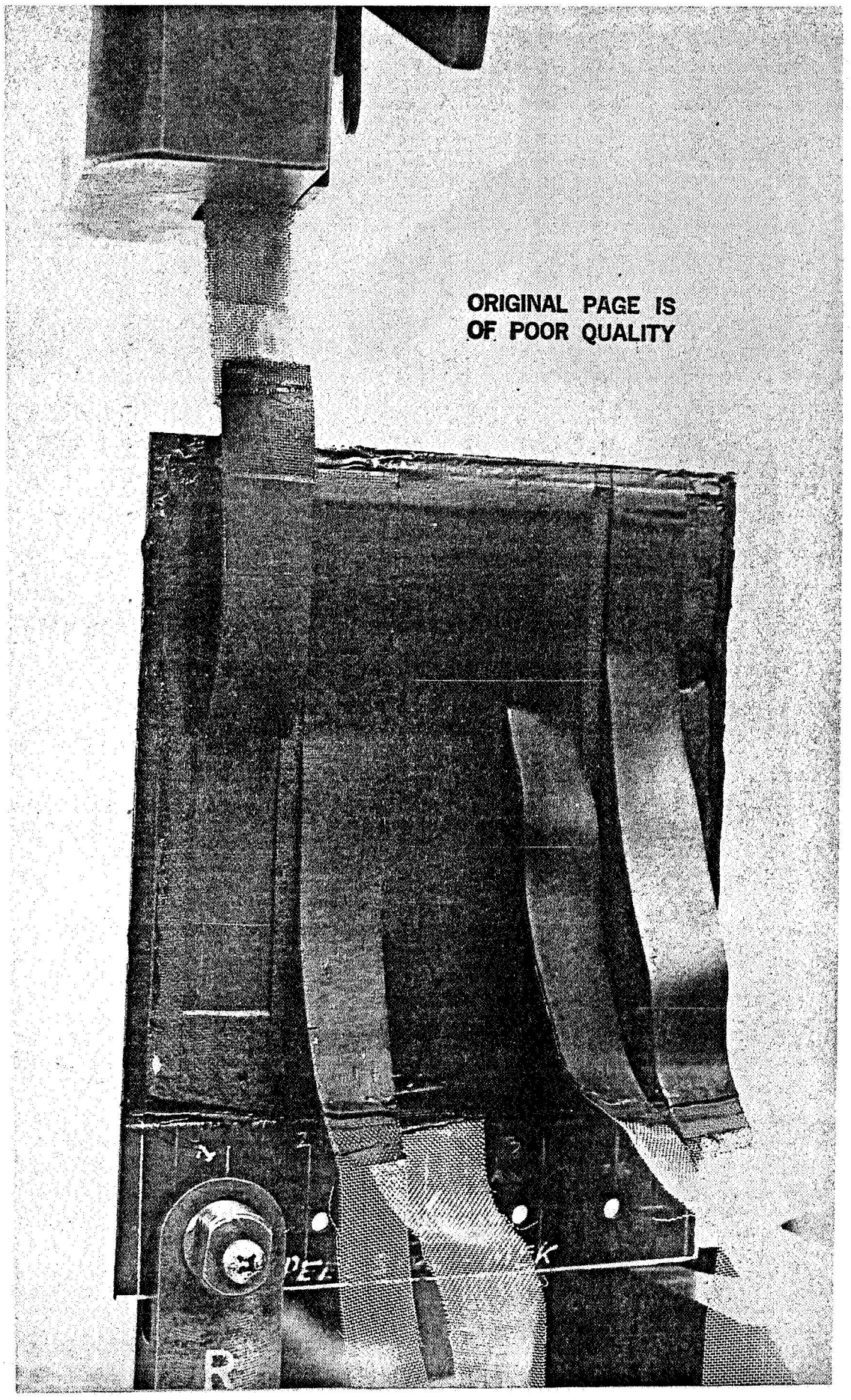


Figure 3-10: Results of 180° Peel Tests

The results of the 180° sealant peel tests are tabulated in Table 3.3 and in Figures 3-11, 3-12 and 3-13.

After each 1 inch of peel, the sealant was cut through to the graphite surface to try to induce adhesive failure. The specimen showing very low peel strength, No's. 9, 10, (Figure 3-12) 5, and 6 (Figure 3-13), all failed adhesively, in the sealant/composite interface, exposing the bare composite surface. All other specimens failed cohesively, leaving sealant on each failed surface. In specimens 12, (Figure 3-12) 7 and 8, (Figure 3-13) the wire screen ruptured during the test, indicating adhesive strength in excess of the tensile strength of the screen.

MIL-S-8802E specifies 20-to-40-mesh aluminum or monel wire fabric, aluminum was selected for these tests due to it being readily available whereas monel was not. In retrospect, however, monel should have been used because of its higher strength so that the wire screen failures in Figure 3-12 and 3-13 would have been avoided.

All of the peel tests indicate that adhesion by the PR 1422 sealant is enhanced by application of MIL-C-27725 fuel tank coating. It is also apparent from the data in Table 3.3 that the surface cured adjacent to the peel ply shows better adhesion with the PR 1422 sealant than that cured next to the silicone rubber surface.

Conclusions to be drawn from the results of the surface preparation tests are the following:

a) In both lap shear and peel tests, composite cured adjacent to peel ply proves to be better adhered than composite cured adjacent to silicone rubber sheet. A possible explanation for this observation may be impregnation of the graphite/epoxy composite surface by residual monomers or low molecular weight oligomers in the silicone rubber loading to lower adhesive strengths.

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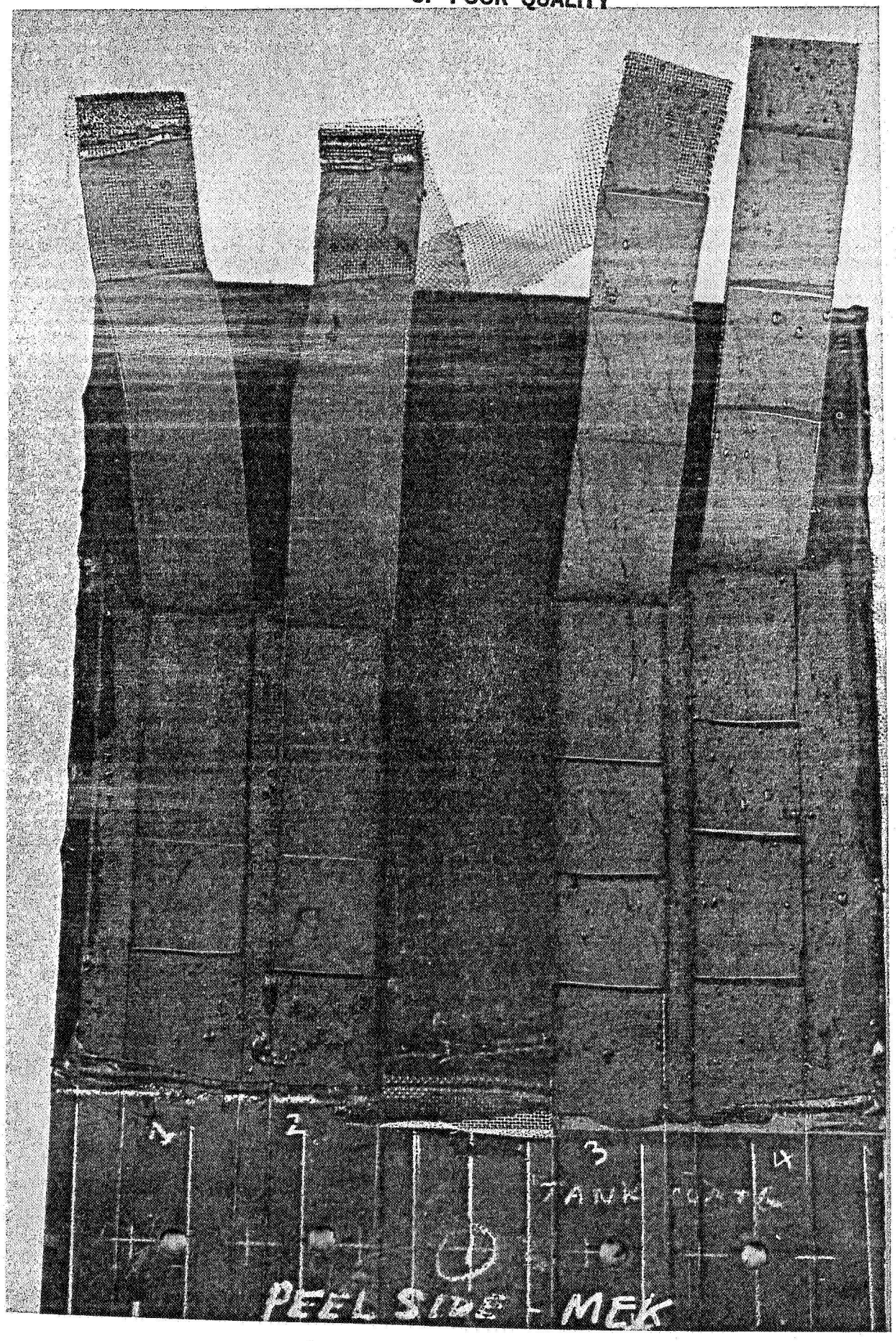


Figure 3-11: Results With MEK Only Wipe On Strips 1 And 2, And With MEK Wipe And Fuel Tank Coating on Strips 3 and 4.

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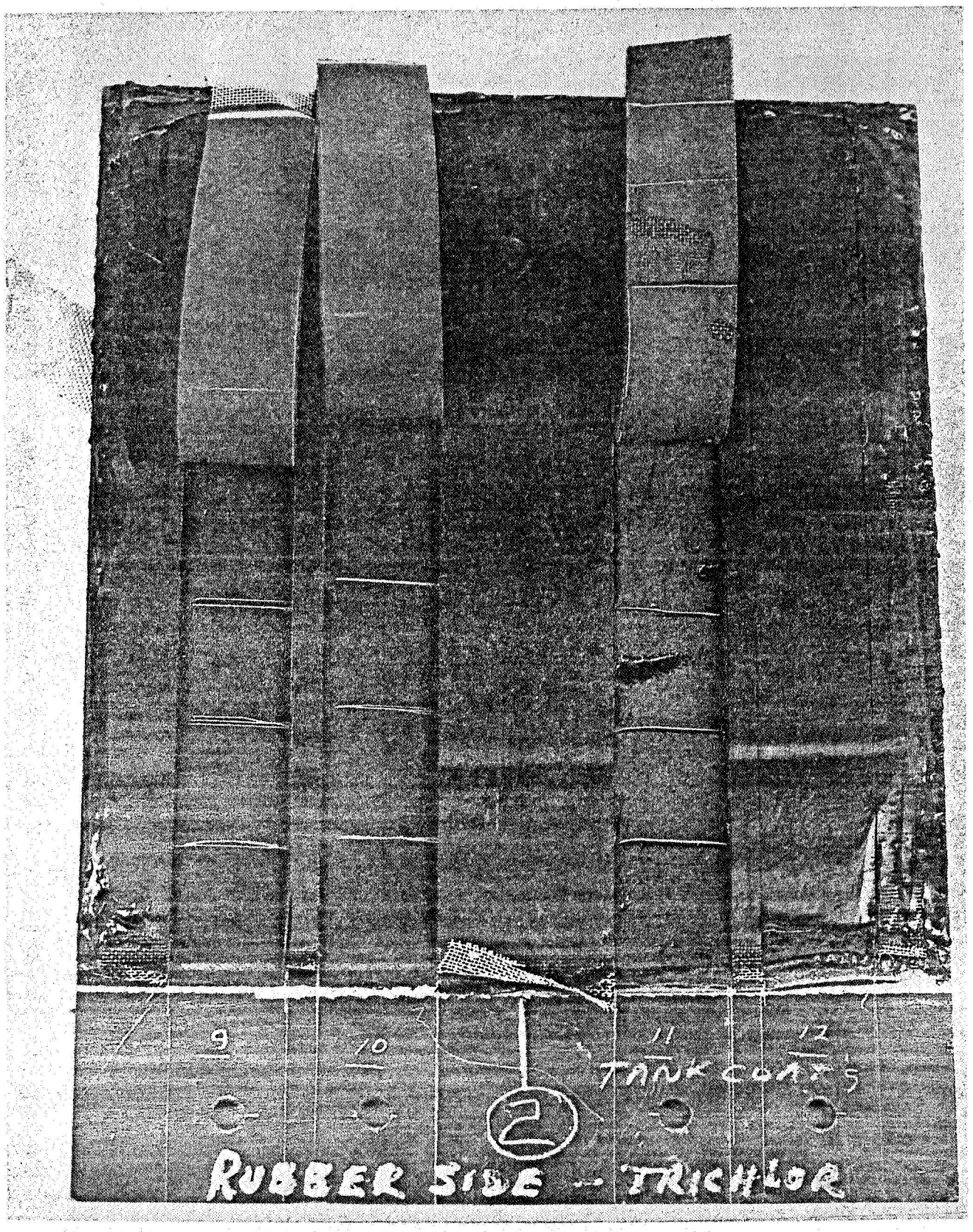


Figure 3-12: Results With Trichlor Wipe Only on Strips 9 And 10, and With Trichlor Wipe and Fuel Tank Sealant on Strips 11 and 12.

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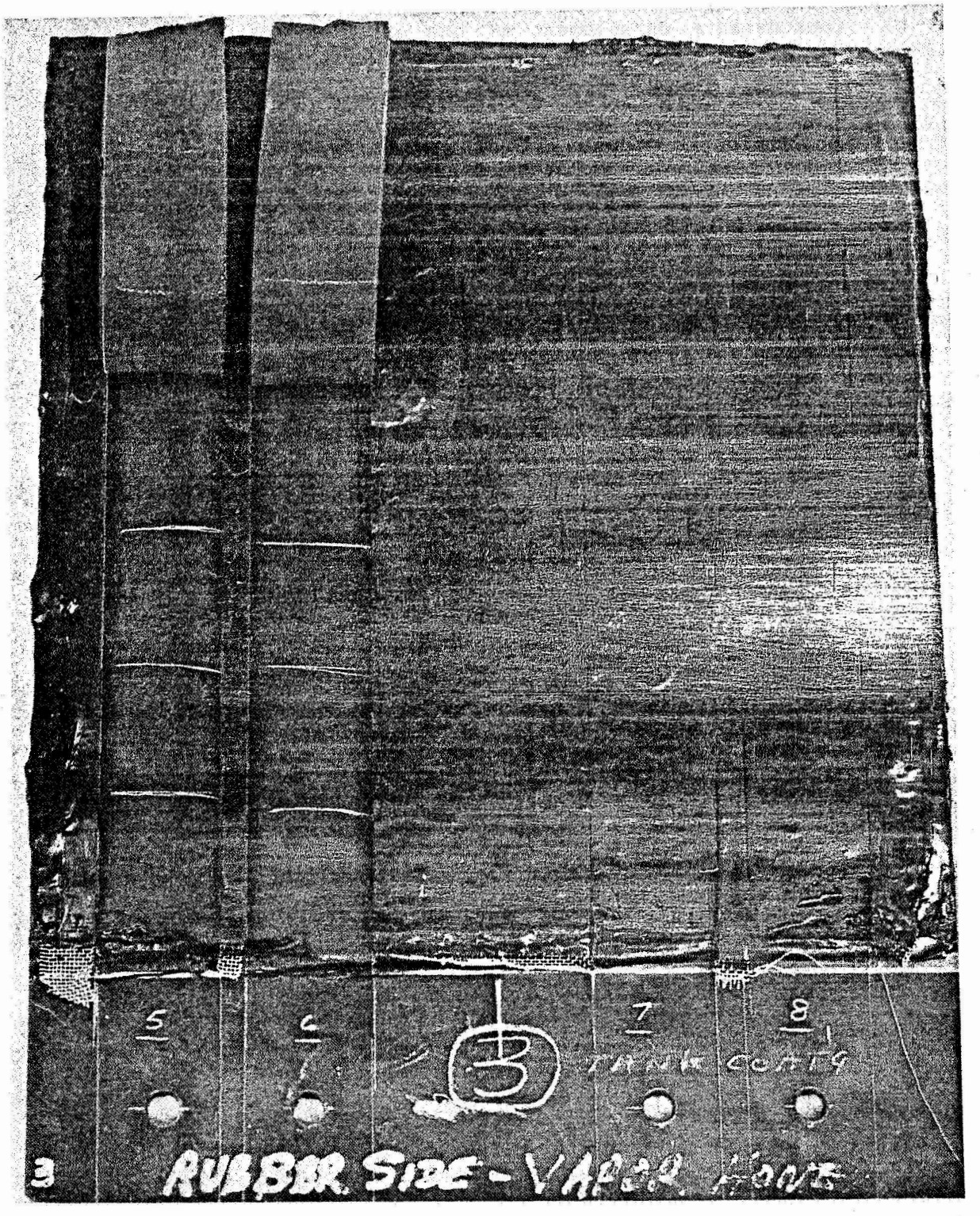


Figure 3-13: Results With Vapor Honed Only on Strips 5 and 6 And Vapor Honed and Fuel Tank Sealant on Strips 7 and 8.

b) Considerable enhancement of the adhesion of the composite surface to the PR 1422 sealant is effected by application ofthe MIL-C-27725 fuel tank coating to the composite surface.

c) Application of MIL-C-27725 fuel tank coating to the faying surface of lap shear specimens bonded with a high strength adhesive such as AF-10 results in degradation of adhesive strength by about 20 to 25%. If this loss can be tolerated, then surface application of the fuel tank coating can be used with adhesively bonded composite specimens.

3.2 FUEL CONTAINMENT

3.2.1 Laminate Fabrication

In preparation for coupon fabrication for fuel containment tests, two fastener and sealing effectiveness laminates were fabricated. These laminates, designated IYX1834 and IYX1835, 24-ply, AS4/3502, fiber orientation $(\pm 45, 0, 90)_{3S}$, were examined by C-scan and found to be free of defects. The measured values for resin content and cured thickness per ply are shown in Table 3.4. The fiber orientation was verified by ply count/orientation 2° grind down.

3.2.2 Specimen Fabrication

Fuel sealing tests were conducted to compare the behavior of a bolted graphite/epoxy joint sealed with a polysulfide sealant to a joint which has been bolted and adhesively bonded. Cyclic load, sustained load, and cyclic temperature tests were conducted with simultaneously applied pressurized fuel.

The single lap shear test specimens were constructed using a 24-ply quasi-isotropic layup of AS4/3502. The specimens were 3.5 inch wide and connected with three 3/16 inch diameter fasteners (NAS 4603U5 pins with HL94LP-6 collars) as shown in Figure 3-14.

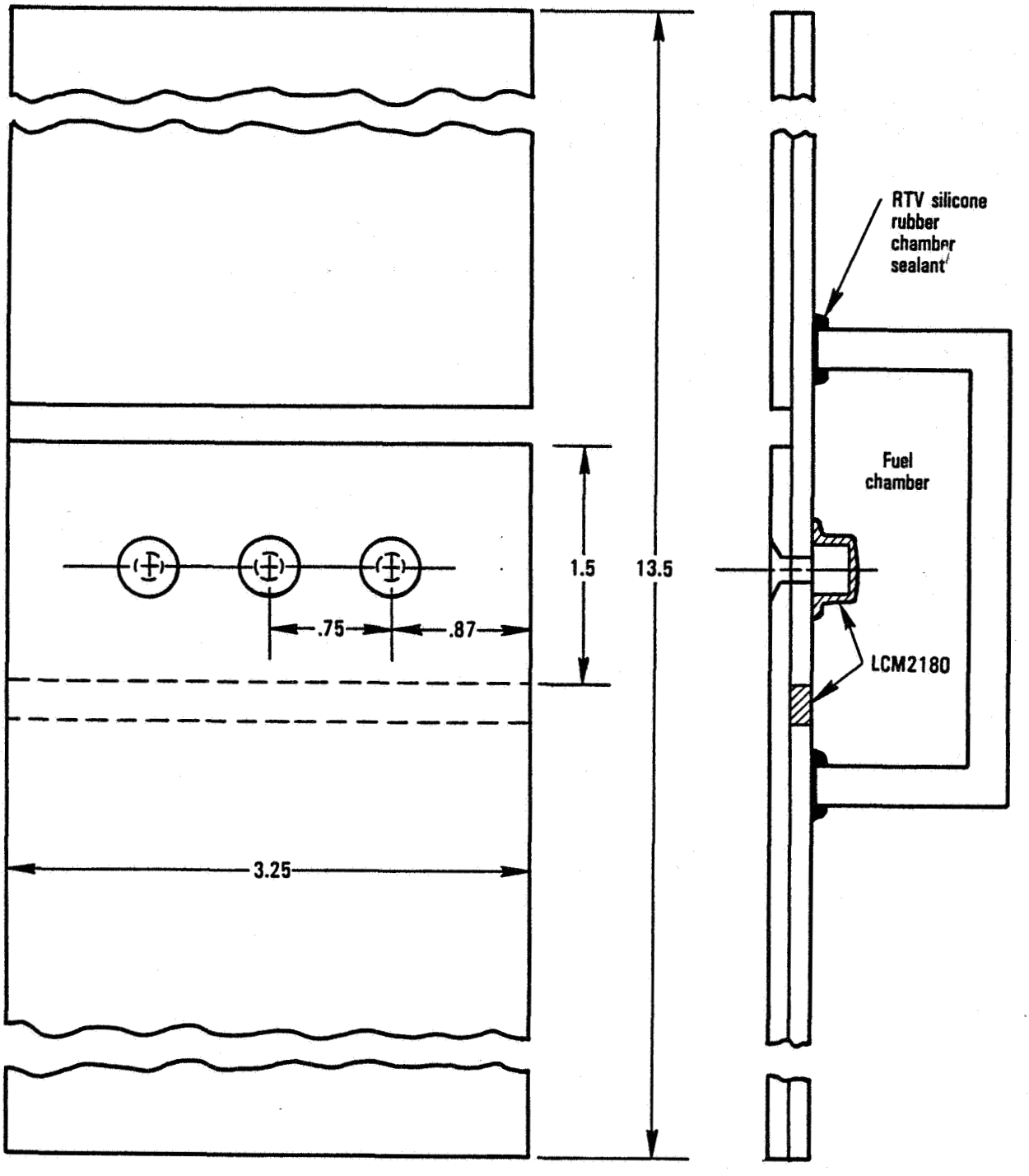


Figure 3-14: Fuel Sealing Lap Joint Geometry.

TABLE 3.4 - FASTENER AND SEALING EFFECTIVENESS LAMINATES

Laminate Designation	Resin Content	Cured Thickness/Ply
IYX1834	33.08 30.97 Avg. 32.2% 32.61	0.126 mm (0.00496 in.)
IYX1835	33.37 32.63 Avg. 33.2% 33.73	0.131 mm (0.00514 in.)

Lap joint shear specimens representing bonded or sealed faying surfaces, and nominal or maximum hole sizes were fabricated as shown in Tables 3.5 and 3.6, for restrained load testing with fuel under pressure on one side of the joint. Figure 3-14 and 3-15 show how the fuel containment boxes are attached to the specimens on the collar side. On all specimens, sealant (LCM2180) was applied to the collars and in the joint fillets as indicated in Figure 3-14. The back (collar) side of the joint had the entire 1/4 inch gap between the specimen and the tab filled with sealant so that the boxes would not leak. Prior to placement of the boxes on each specimen a bead of RTV silicone rubber was applied to the box face and on the mating surface of the specimen, then mated together and bolted finger tight down to 1/16 inch spacer pins loacted in the outboard corners of the box. After a 24-hour cure the spacer pins were removed and the four bolts were further tightened to prevent fuel pressure from rupturing the bond.

3.2.3 Fatigue Testing

Eight specimens were tested in a 50 kip MTS computer controlled fatigue machine, shown in Figure 3-16, with combined cyclic load and static pressure. The loads were 36,000 cycles of 1930 lb tension, 579 lb compression (R = -0.3) and 36 cycles of 3088 lb tension, 926 lb compression combined with 15 psi fuel pressure. Four of the specimens were bolted and bonded and four of the specimens were bolted. Within each test group one specimen had nominal size bolt holes. One specimen had bolt holes the maximum size allowed by the drilling specification (+0.003 in.); one specimen had a delaminated hole; and one specimen had a hole drilled non-perpendicular (2^{o}). None of these specimens leaked during the fatigue test.

3.2.4 Sustained Load Tests

After the fuel pressure boxes were attached to the specimens they were placed in Satec creep machines shown in Figure 3-17. For mounting, a single 1/2 inch diameter hole was drilled 0.95 inch from each end and was pin

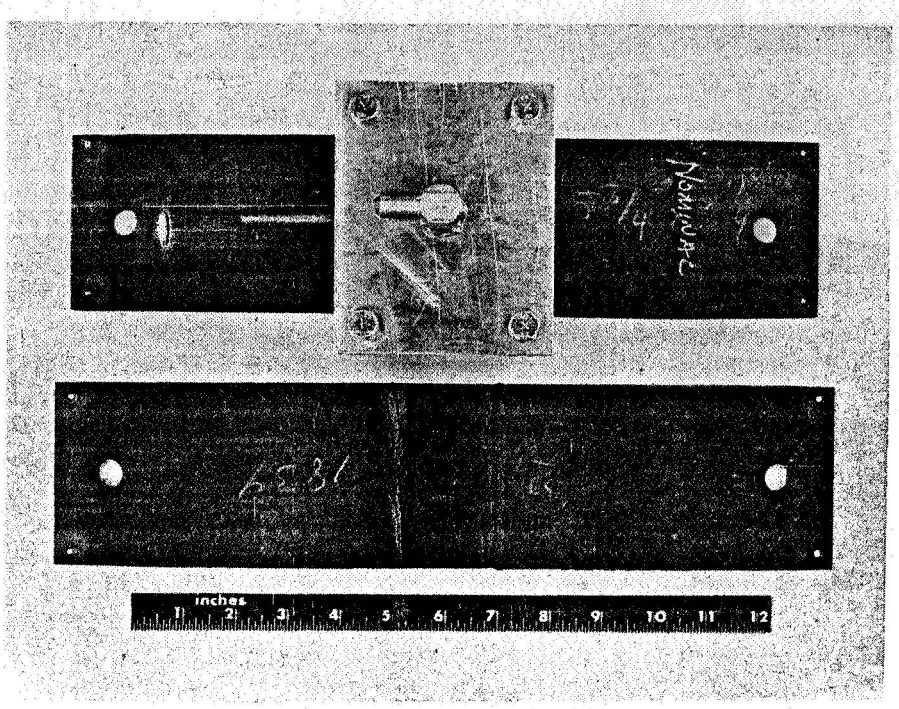
TABLE 3.5 - SEALING EFFECTIVENESS LAP SHEAR SPECIMEN DESIGNATIONS

Specimen Type	Preparation Method	Specimen I.D.	Hole Condition	Test Type
Sealed Joint	MEK Wipe LCM 2180 Wet Install Fasteners Fillet & Collar Seal	17, 18	Nominal	Fatigue
		19, 20	Max Size	Fatigue
		21, 22	Non-perpendicular	Fatigue
		23, 24	Delaminated	Fatigue
		25, 26	Nominal	Creep
		27, 28	Max Size	Creep
		29, 30	Nominal	Thermal Cycle
		31, 32	Max Size	
Bonded Joint	MEK Wipe EC1290 AF 10 Dry Install Fasteners Fillet & Collar Seal	1, 2	Nominal	Fatigue
		3, 4	Max Size	Fatigue
		5, 6	Non-perpendicular	Fatigue
		7, 8	Delaminated	Fatigue
		9, 10	Nominal	Creep
		11, 12	Max Size	Creep
		13, 14	Nominal	Thermal Cycle
		15, 16	Max Size	

TABLE 3.6 - FASTENER HOLE CONDITION

Specimen Type	Hole Size (in.)	Condition
Nominal hole	0.1890 - 0.1920	No defects
Maximum hole	0.1930 - 0.1940	No defects
Non-perpendicular hole	0.1890 - 0.1920	Tipped 2° in longitudinal direction
Delaminated hole	0.1890 - 0.1920	Drilled without backup Push drill thru last 3 plies

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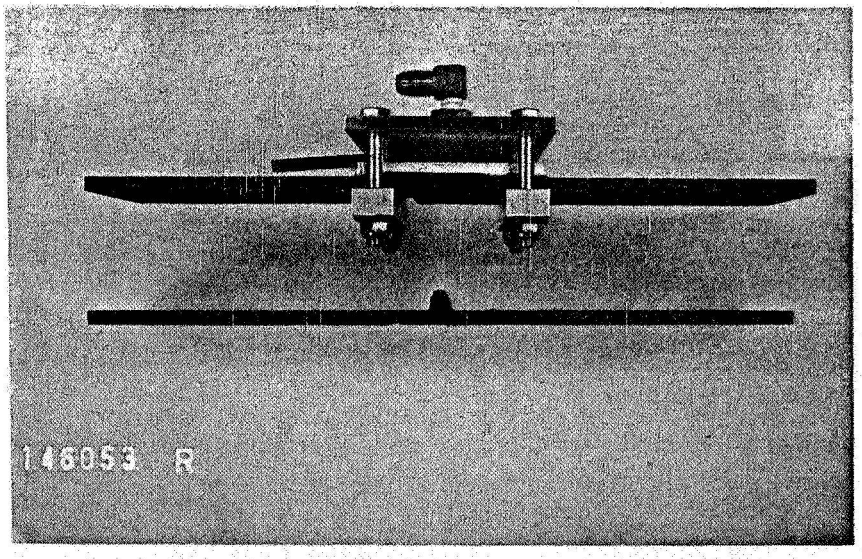


Figure 3-15: Lap Joint Specimen Showing Fuel Containment Box Installation.

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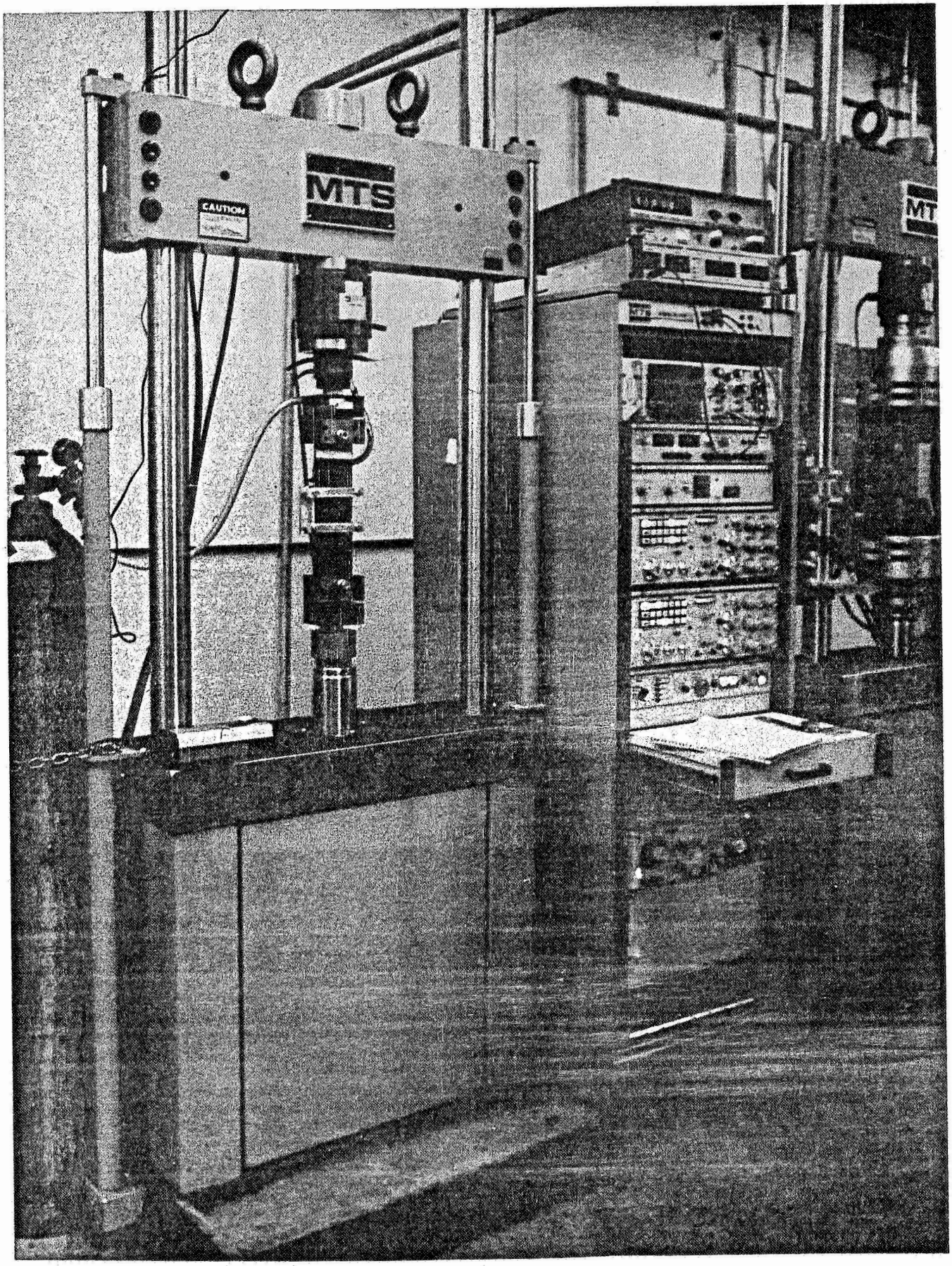


Figure 3-16: Cyclic Fatigue Test Setup With Fuel Pressure Box and Pressure System Attached to Lap Joint Specimen.

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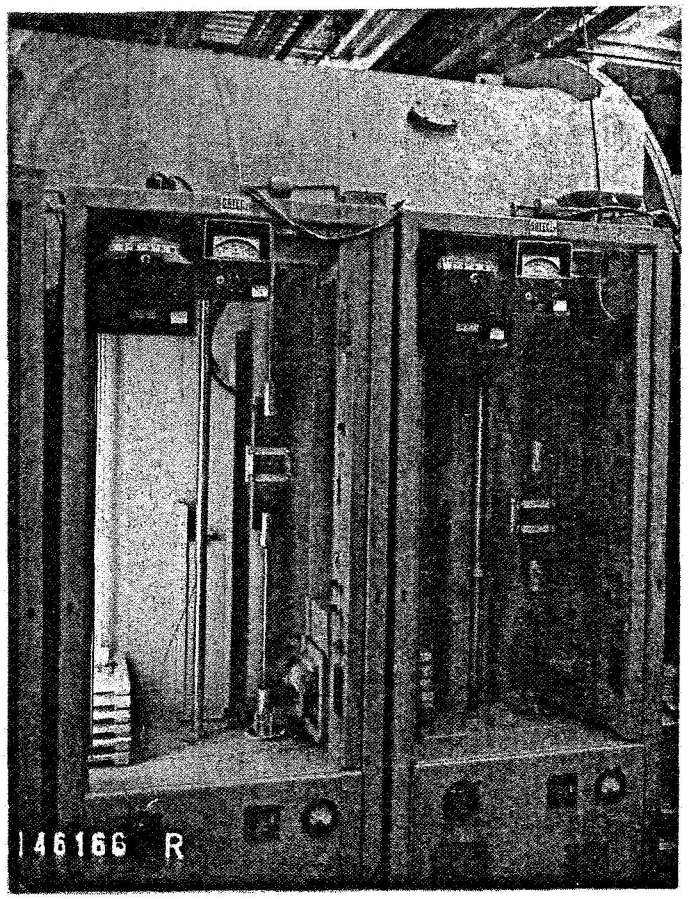


Figure 3-17: Two Creep Machines

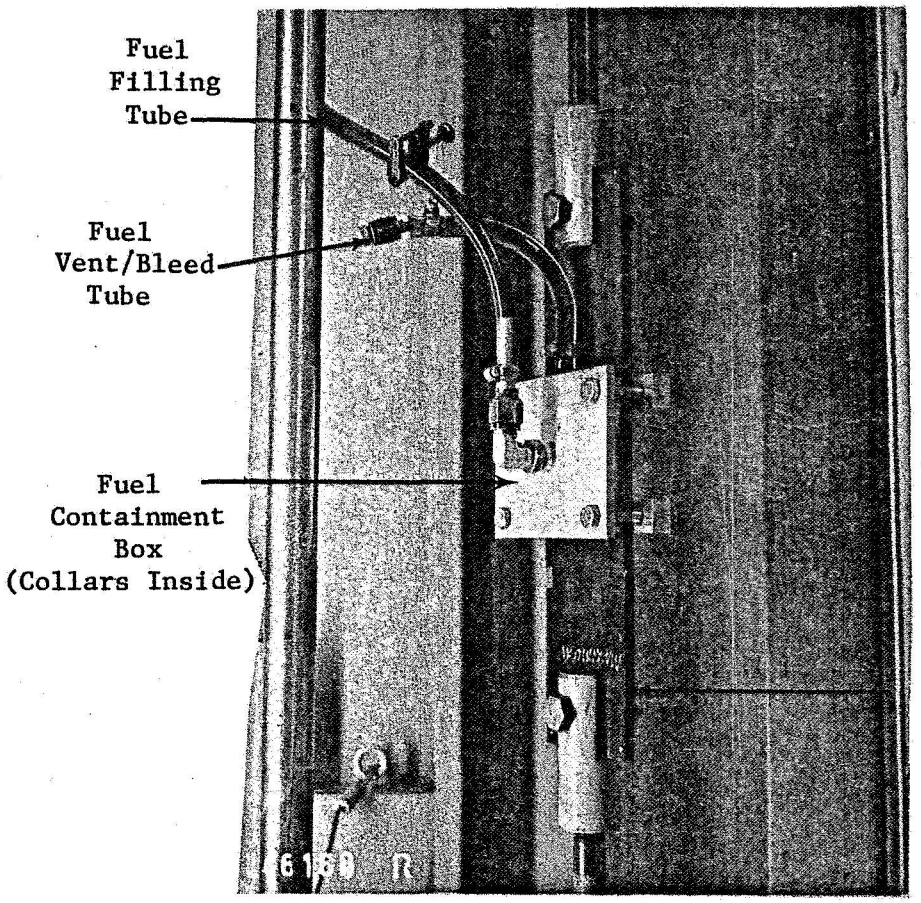


Figure 3-18: Detail View of Fuel Filling System

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loaded as shown in Figure 3-18. Fuel lines were then attached to each box from a central container. A 6-inch vent/bleed tube was attached to each chamber and fuel was fed to the boxes until it became visible in the vent tube at which time the vent was closed. This assured that the box was completely full. After all four boxes were filled, the fuel reservoir was closed off from the fill lines and the system was pressurized to 15 psi.

The fuel used was Shell Pella A with equal mixtures of fluorescent dyes added to enhance visibility of small amounts of leakage. The dyes were: 1) BASF Wyandotte Corp, Floural yellow 088 (5G); and 2) Morton Chemical Company, Fluorescent yellow FGSC. These were selected based on their solubility in Pella A and their emission intensity under long wave (366 NM) ultraviolet light. With the room lights dimmed each specimen was inspected with an ultraviolet light for leakage. Each specimen was then loaded to 1930 lb and reinspected for leaks. The applied axial load of 1930 pounds generates a calculated gross area axial strain of 675 in/in and a calculated bearing stress of 28.2 ksi. At least once every four hours the specimens were checked for leaks and pressure maintenance. After 300 consecutive hours under load and pressure no leaks occurred.

Loads were increased to 4000 lb at 15 psi and held for another 200 hours. No leaking occurred. The pressure was then increased to 20 psi with the 4000 lb load again no leaks were seen.

Specimens were removed from the creep machines and placed, one at a time, in a 50 kip MTS machine with hydraulic grips. The fuel system was re-connected and pressurized to 15 psi. An axial tension load was then applied at the rate of 0.05 in/min. head displacement while the specimen was being observed under ultraviolet light for first sign of leakage. Load-stroke plots were made of each specimen to failure or leak. Table 3.7 summarizes each specimen type, failure load or leak load, jack stroke, and failure type.

TABLE 3.7 - CREEP SPECIMEN RESIDUAL TENSILE STRENGTH TESTS

Specimen I.D.	Type Specimen	Hole Condition (size)	Leak Load (lb)	Jack Stroke (in.)	Failure Type
9, 10	Bonded	Nominal	9,448 ①	0.0439 ②	Intralaminar shear/tensile
11, 12	Bonded	Maximum	10,700	0.0412	Bond
25, 26	Sealed	Nominal	6,602	0.0848	Sealant Rupture
27, 28	Sealed	Maximum	6,586	0.0987	Sealant Rupture

① Max load, leak visible after load drop-off.

② At max load, total stroke to leak was 0.0622 in.

During loading of bonded specimen 9, 10 (Figure 3-19) a loud pop was heard at 9,448 lb, and the load dropped off to about 5,000 lb, then continued to load since the test machine was under a ramp loading rate control. The test machine was then put in a hold and the data gathering computer stopped. A detailed inspection revealed no leakage, therefore the test was resumed as shown in Figure 3-20. Another loud pop was heard at 6,000 lb, and the load again dropped off, but no leakage was noted so loading continued. A third loud pop occurred at 4,900 lb with major leakage visible on the surface of the countersunk fastener head side (#10). Tensile failure occurred, as shown in Figure 3-21, through the fastener holes in the countersunk piece (#10) only. The collar side piece (#9) showed no similar damage. After failure, the fasteners were removed to permit inspection of the joint faying surface and fracture, shown in Figure 3-22. The bond does not appear to have ruptured. The failure is predominately intralaminar shear in 0^{o} plies in both pieces.

Bonded specimen 11, 12 was loaded in the same manner as specimen 9, 10 (Figure 3-23). At the first loud pop, leakage occurred at the joint edges (Figure 3-24) not through the fasteners as in specimen 9, 10. Failure and leak occurred simultaneously at 10,700 lb. An examination of the fracture surface after fastener removal (Figure 3-25) reveals a totally different failure mode than specimen 9,10. The specimen exhibits primarily a bond failure with some 45^{o} ply fibers still imbedded in the AF10. Most of the adhesive remained on piece #12 (Figure 3-25), the countersunk face sheet, although some debonding did occur on the reverse piece (#11). No multiple pops occurred during this test, the load ramped up continuously to final failure (Figure 3-23). Also no tensile fractures were visible between the fasteners of the countersunk sheet. The total stroke to leak was only 0.0412 inches whereas on specimen 9,10 leak did not occur until 0.0622 inch although the initial failure was at 0.0439 inch.

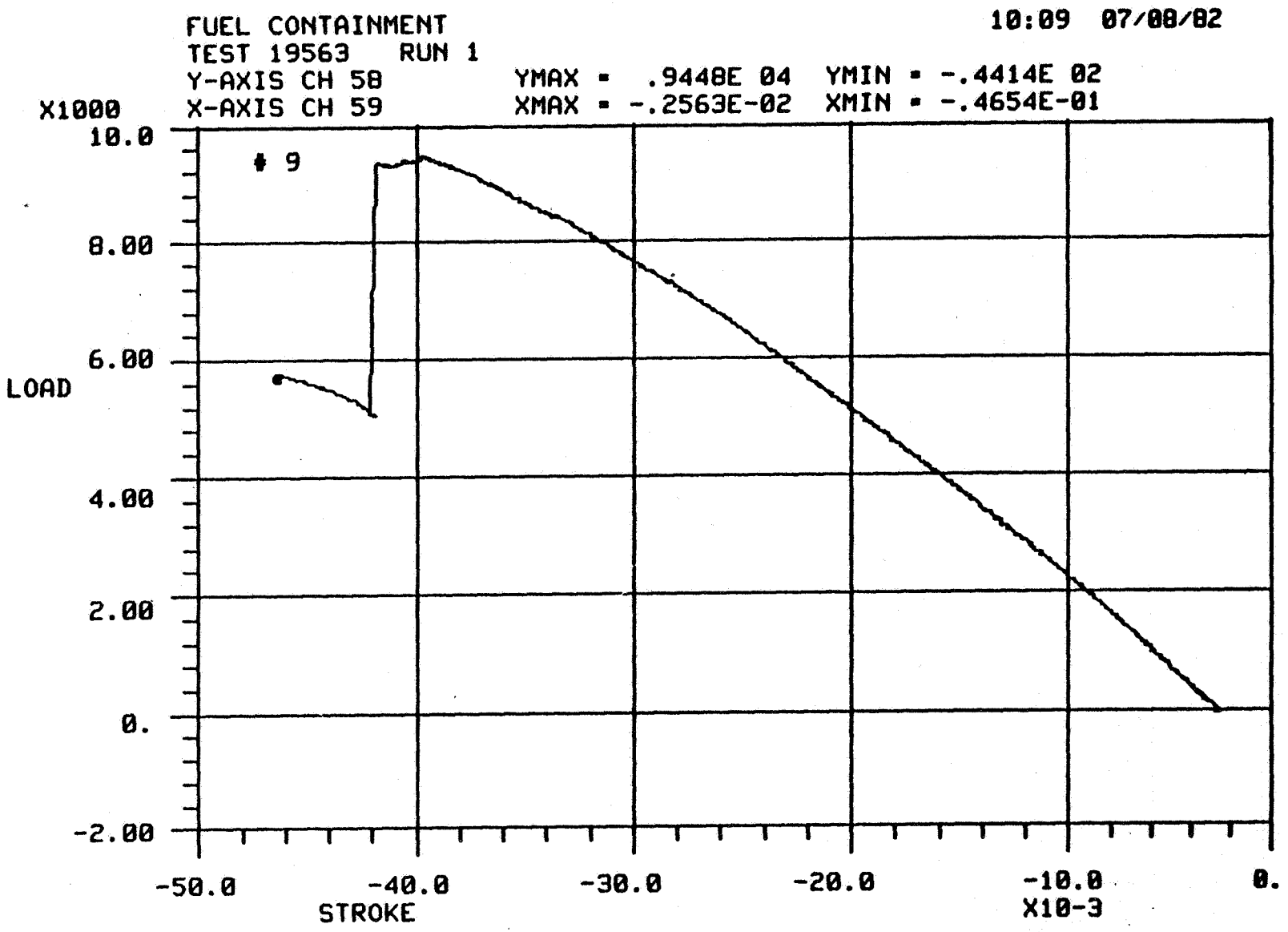


Figure 3-19: Load-Stroke Curve for Bonded Specimen 9/10.

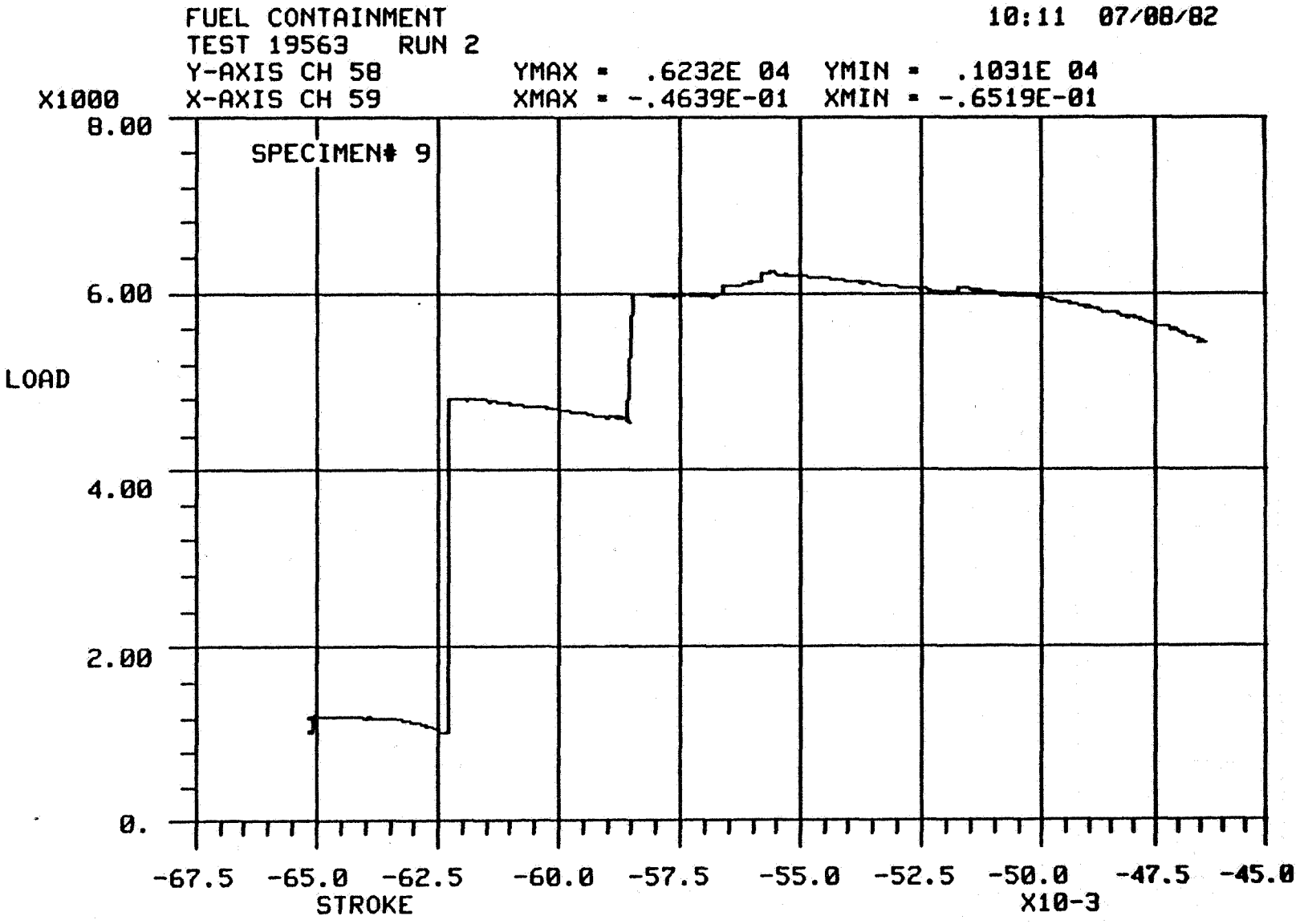
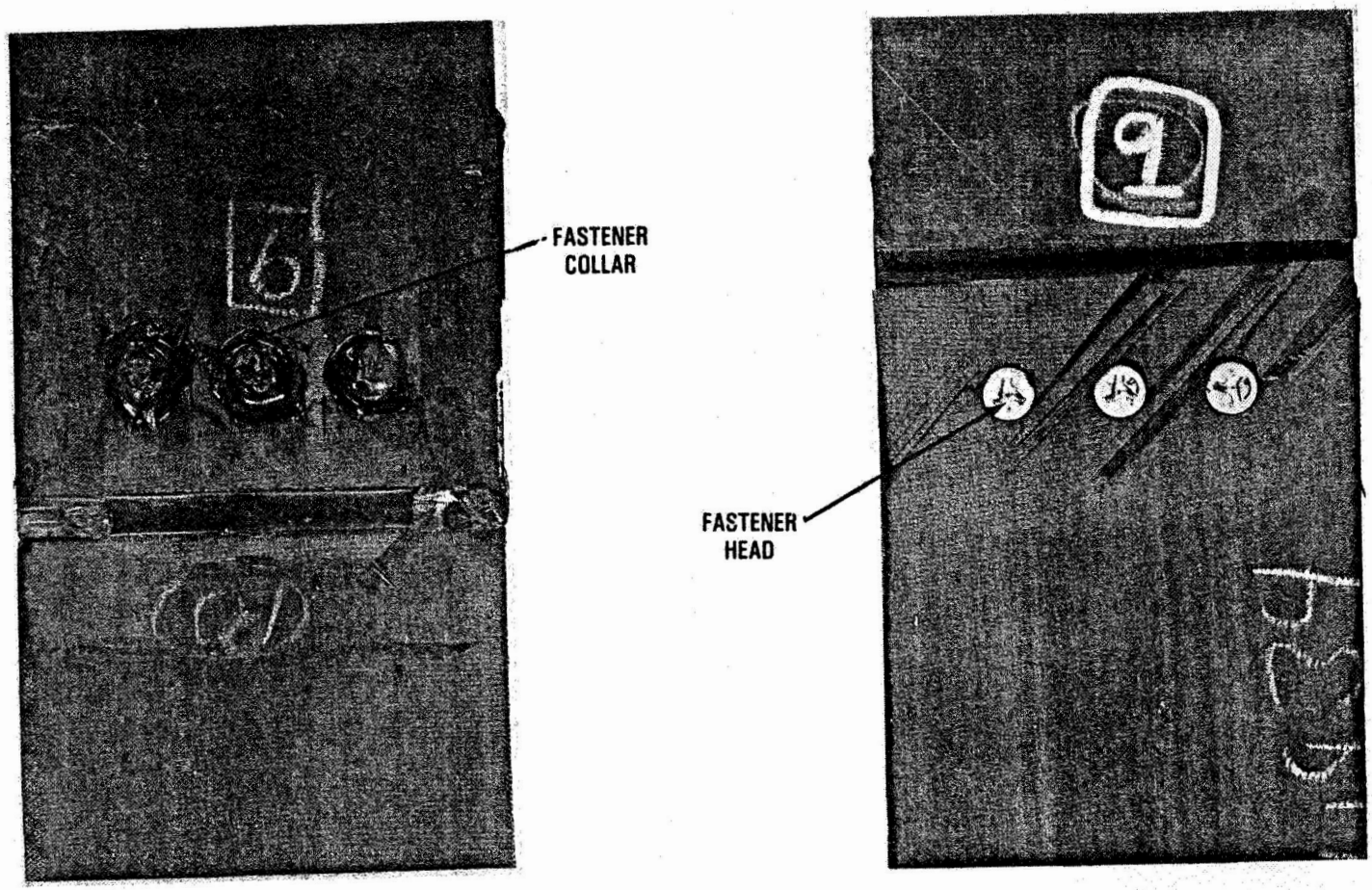


Figure 3-20: Continuation of Test on Specimen 9/10 From Figure 3-19.



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Figure 3-21: AF10 Bonded Joint Static Tensile Failure. Holes are Nominal Size.

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Figure 3-22: Failure of Bonded Specimen Showing Predominately Intralaminar Shear of 0^{o} Plies and Tensile Failure Between Countersunk Fastener Holes.

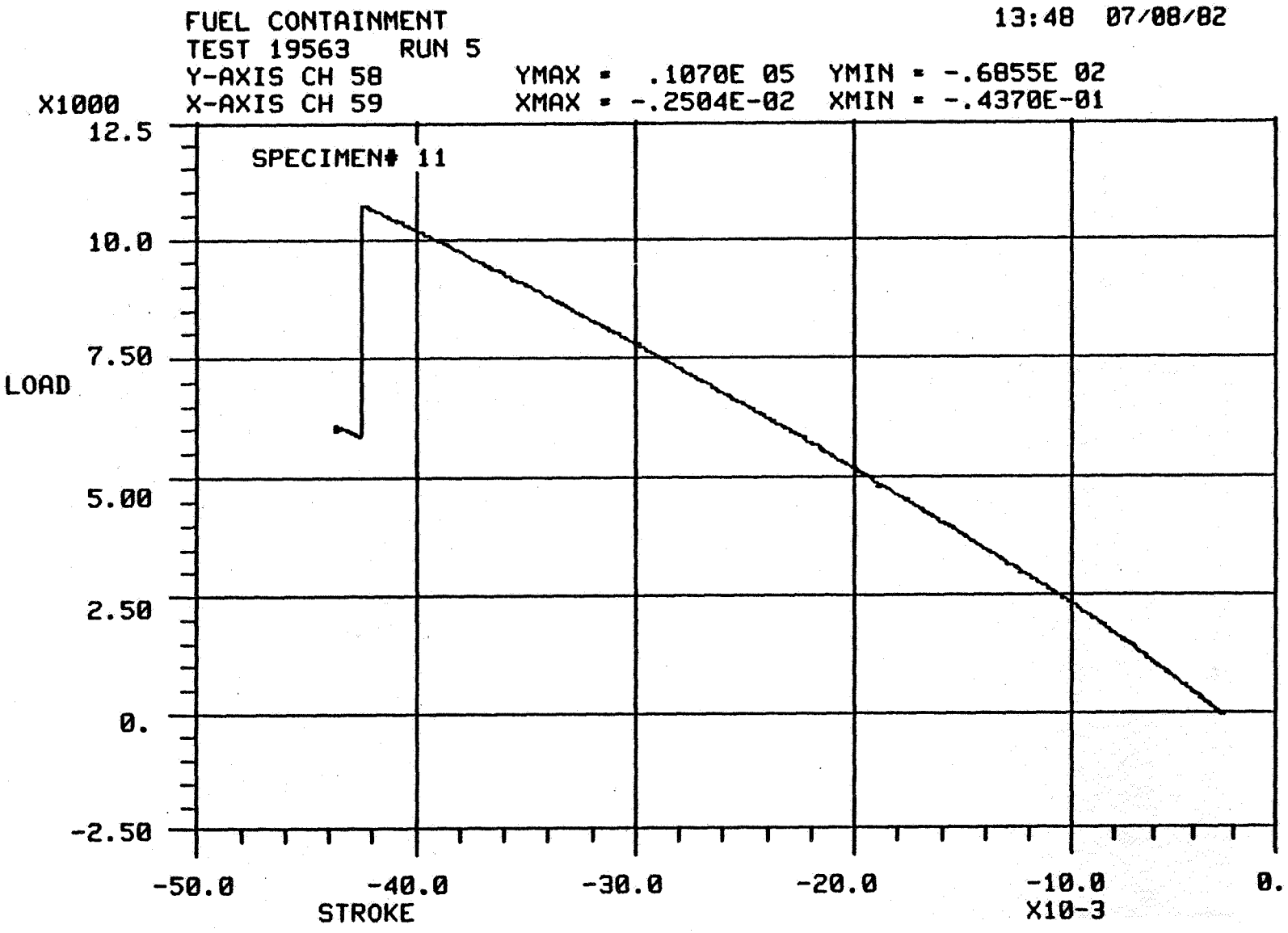


Figure 3-23: Load-Stroke Curve for Bonded Specimen 11/12.

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Figure 3-24: AF10 Bonded Joint Static Tensile Failure. Holes are Maximum Size.Collar Side Damage is Due to Fuel Box Removal.

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Figure 3-25: Failure of Bonded Specimen Showing Predominately Bond Failure. Light Colored Areas in Right Photo Are Adhesive. Damage in Left Photo on Piece #11 was Due to Fuel Box Removal.

Both specimens with faying surface sealant failed in a similar manner by sealant rupture causing a leak on the joint sides (Figures 3-26 and 3-27). Load-stroke curves Figure 3-28 and 3-29 show a smooth rise to leak with no popping as in the bonded joints. No fiber breakage was visible on any of the pieces, nor was there any significant fastener hole distortion (Figures 3-30 and 3-31). Leak loads were 6,602 lb for the nominal hole specimens 25,26, and 6,586 lb for the maximum hole specimen 27.28. Jack deflections at leak were 0.0848 and 0.0987 inch, respectively.

As would be expected, the structural capability of the bolted and bonded joints was superior to the bolted joints. A load of 6,460 lb was considered as design ultimate load on these joints based on a bearing design allowable stress of 94.5 ksi. Since all specimens did not leak at design ultimate load, both sealing methods are adequate for this test condition.

3.2.5 Thermal Cycling Tests

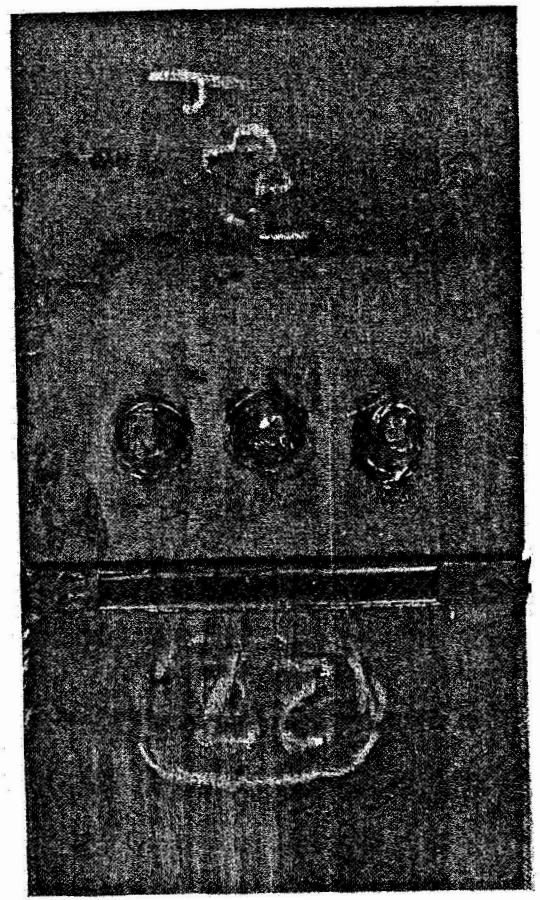
Four lap joint specimens were assembled with faying surface and hole conditions as listed in Table 3.8.

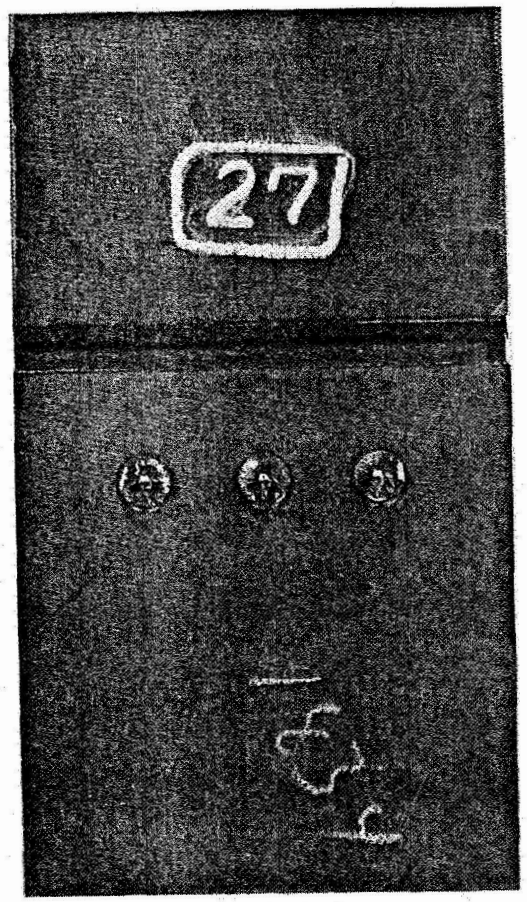
Fuel boxes were attached to each and placed in an environmental chamber shown in Figure 3-32. Fuel was pressurized to 15 psi and held while temperature was cycled 100 times from -65° to 140°F. One thermal cycle required about 40 minutes to go from -65°F to 140° to -65°. Cold temperatures were achieved by injecting CO_2. Heating was by quartz heat lamps. No direct infared radiation impinged on the specimens.

A pressure relief valve was incorporated into the fuel pressure system to prevent over pressure due to thermal expansion so that a uniform 15 psi was maintained over the full temperature range. Specimens were monitored during cycling for leakage and carefully examined after 100 thermal cycles. No leaks were detected in any of the specimens.

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Figure 3-26: LCM 2180 Sealant Joint Static Tensile Failure. Holes are Nominal Size. Note Rupture of Fillet Seal on Left Photograph.





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Figure 3-27: LCM 2180 Sealant Joint Static Tensile Failure. Holes are Maximum Size. Note Rupture of Fillet Seal on Left Photograph.

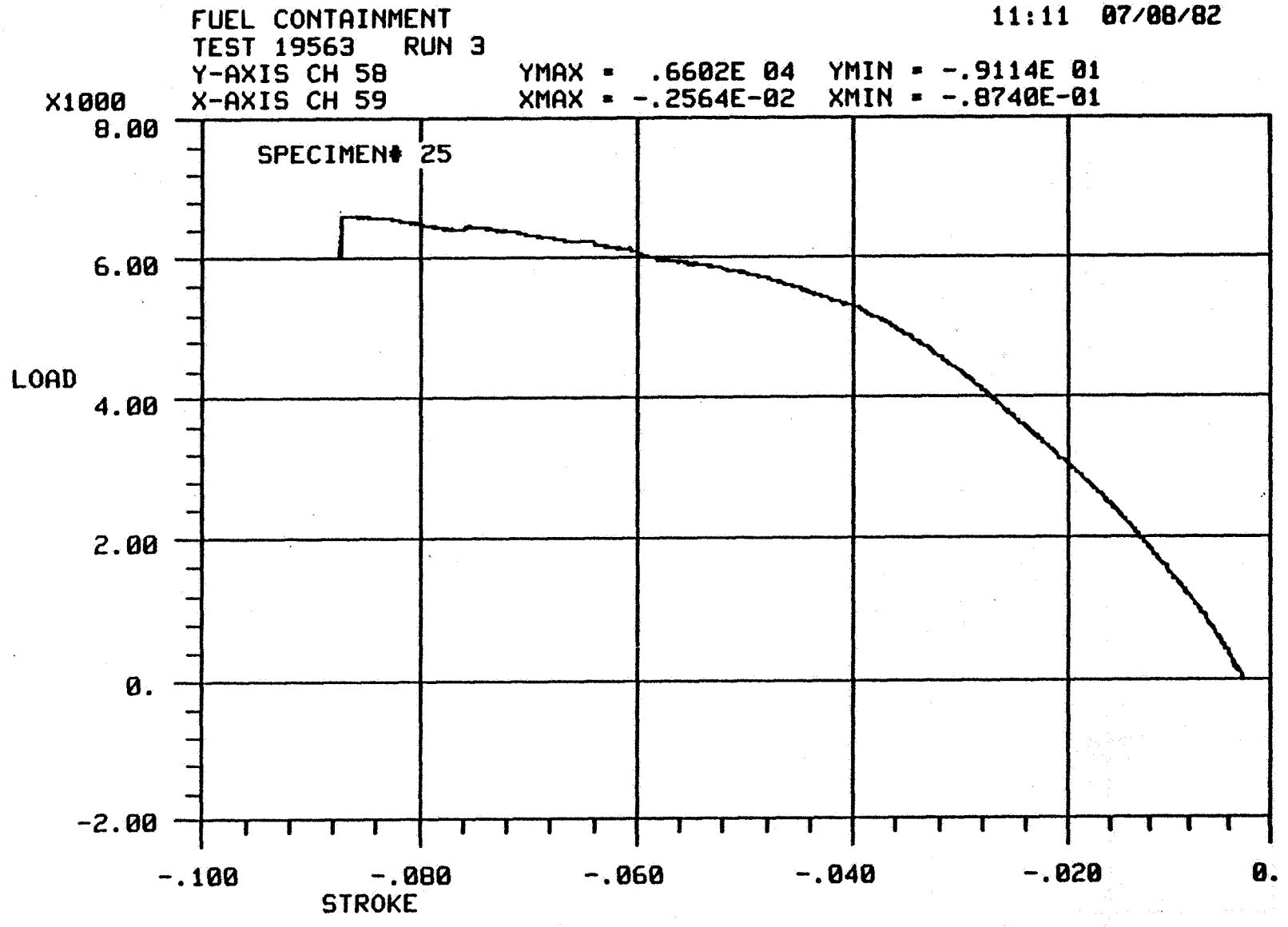


Figure 3-28: Load-Stroke Curve for Sealed Specimen 25/26

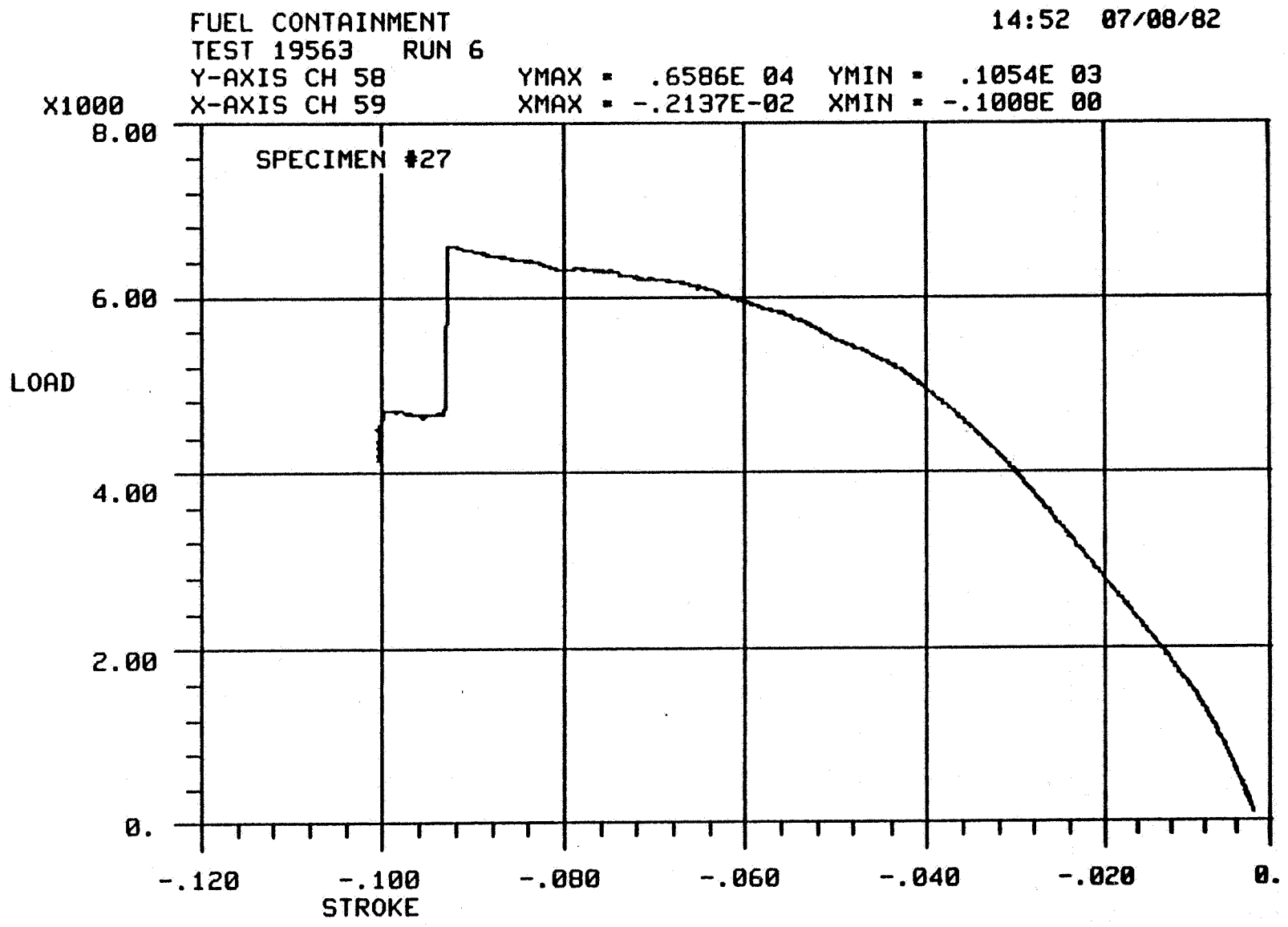


Figure 3-29: Load-Stroke Curve for Sealed Specimen 27/28

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Figure 3-30: Sealed Joint With Nominal Holes After Test with Fasteners Removed.

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Figure 3-31: Sealed Joint With Maximum Holes After Test With Fasteners Removed.

TABLE 3-8 : RESIDUAL STRENGTH TESTS OF THERMALLY CYCLED COUPONS

Specimen ID	Type	Hole Condition	Leak Load * lb.	Failure Type
13/14	Bonded	Nominal (.1890 - .1920)	8549	Intralaminar Shear/ Tensile/Bond
15/16	Bonded	Maximum (.1930 - .1940)	8822	Bond/Intralaminar Shear/Tensile
29/30	Sealed	Nominal (.1890 - .1920)	7236	Sealant Rupture
31/32	Sealed	Maximum (.1930 - .1940)	7203	Sealant Rupture

* Tests conducted at $-65^{o}F$.

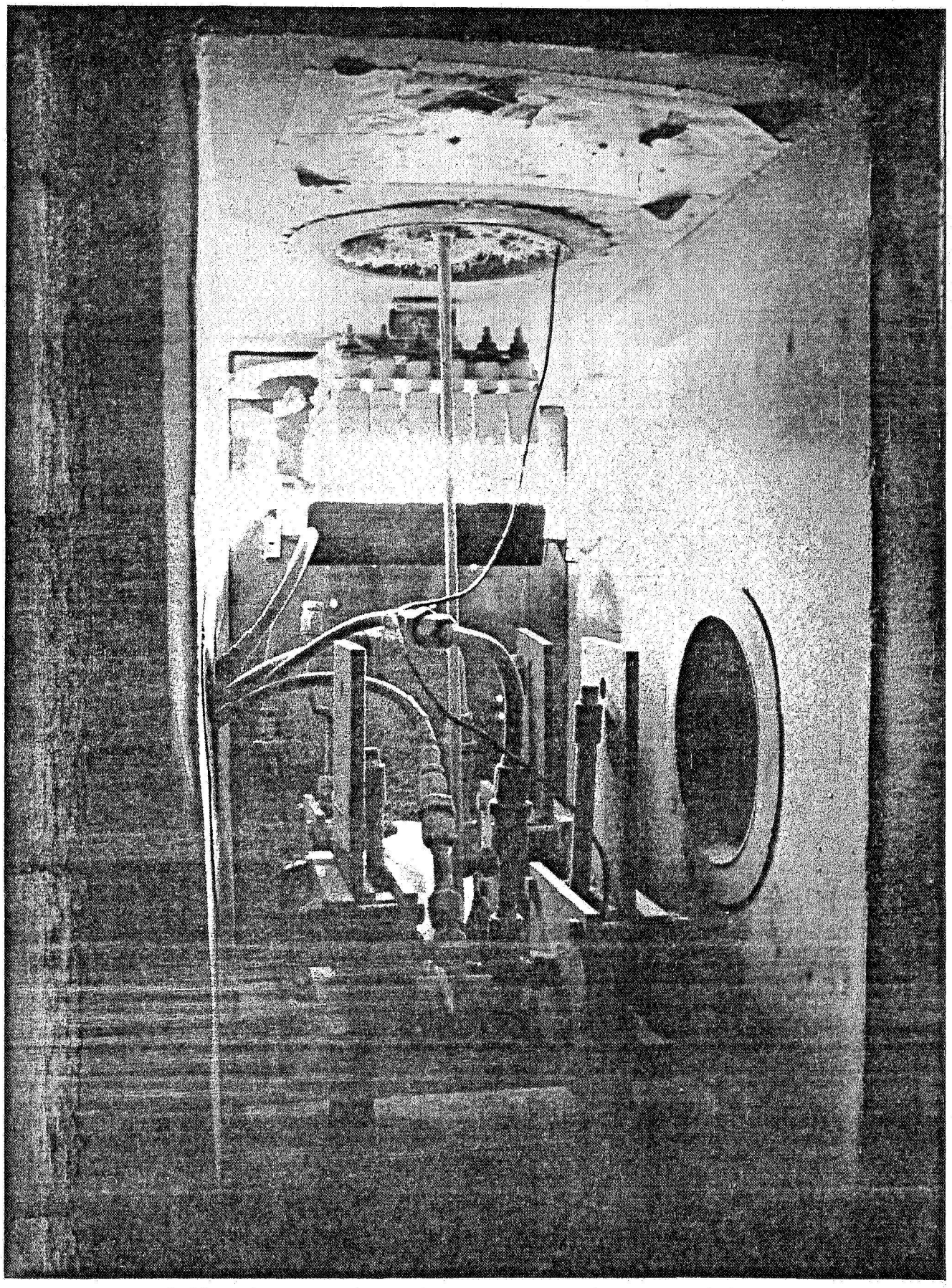


Figure 3-32: Four Lap Joint Specimens With Pressurized Fuel Boxes Attached Are Shown Mounted in a Thermal Cycling Chamber For -65° to -140°F Testing.

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The specimens were then loaded statically in tension to failure at -65°F with 15 psi fuel pressure applied. At -65°F leakage was not noted until the specimens failed. Figures 3-33 through 3-36 show the failed specimens after fastener removal and disassembly. The bonded specimens 13/14 and 15/16 failed partly by bond line rupture and partly by intralaminar shear/tension. Sealed specimens 29/30 and 31/32 failed in net section tension through the fasteners after the sealant ruptured. Load-stroke plots of each test are shown in Figures 3-37 through 3-40. The data from these tests, Shown in Table 3.8, indicate that the -65°F temperature reduced the leak load of the bolted and bonded joints but increased the capability of the sealed and bolted joints. All specimens failed at a load greater than design ultimate load.

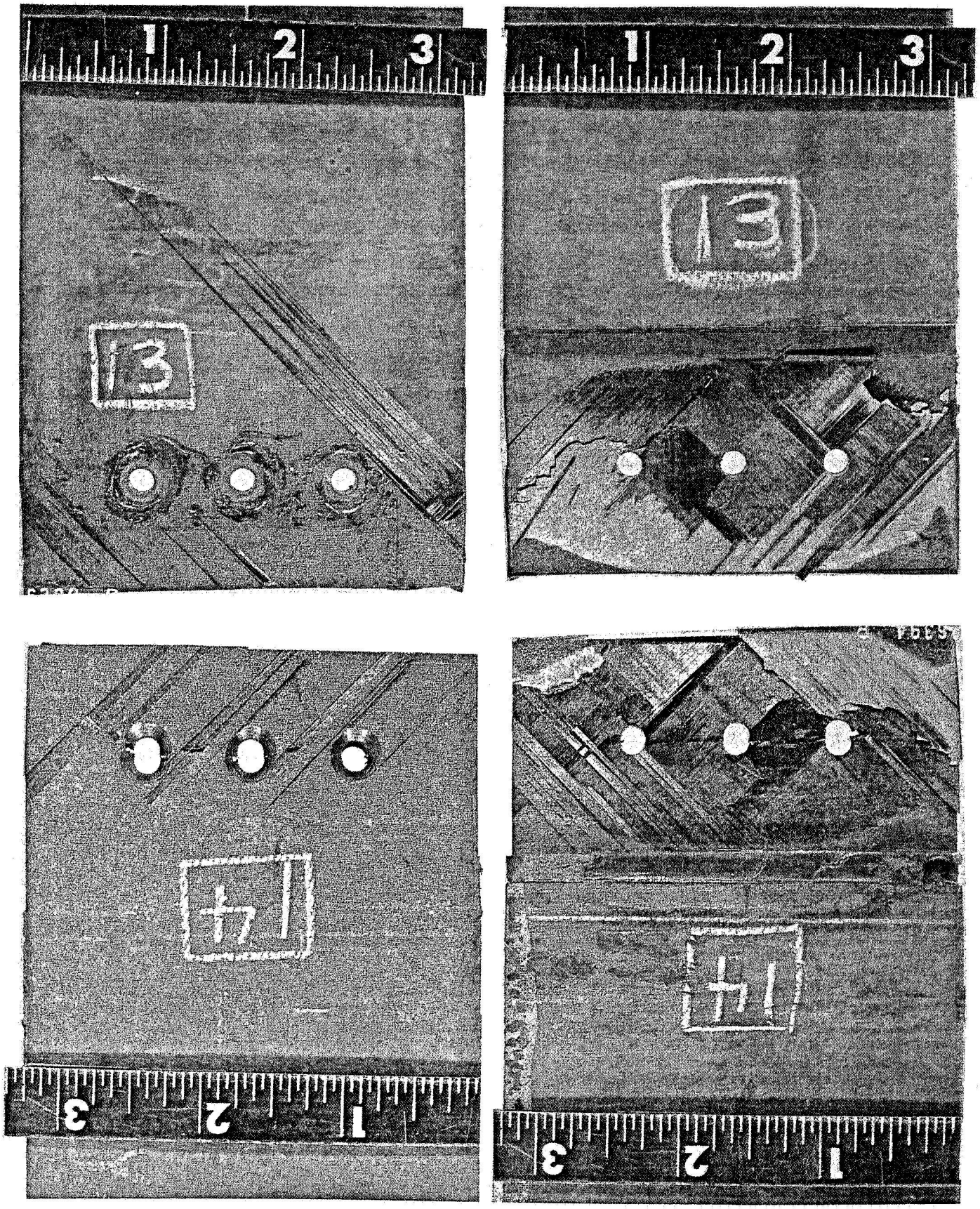


Figure 3-33: Failure of a Bonded Joint Specimen Tested Statically At -65°F. The Photos On the Left Are the Outside Surfaces of The Joint, Those On the Right Are the Faying Surface.

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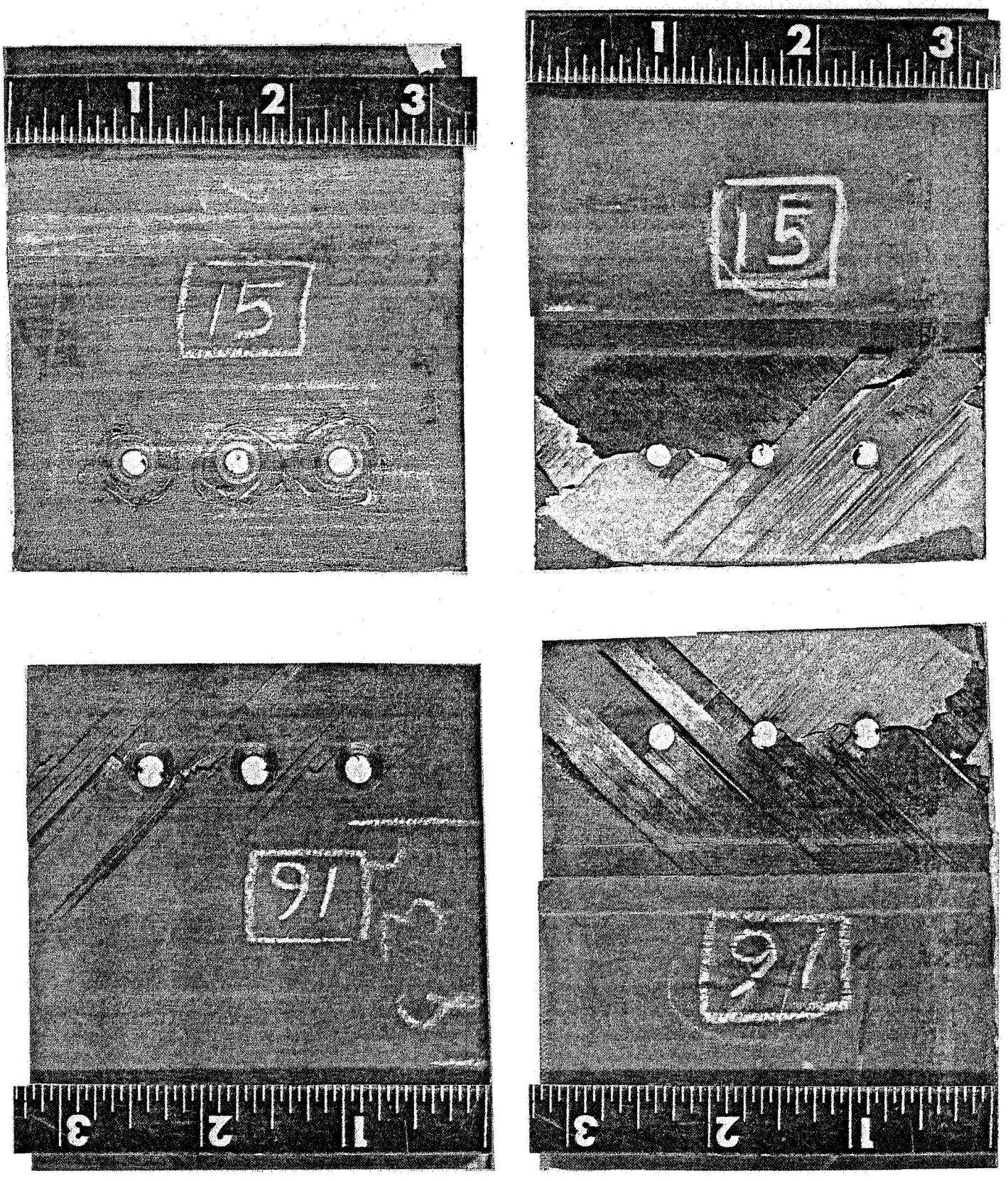


Figure 3-34: Failure of a Bonded Joint Specimen Tested Statically at -65°F.

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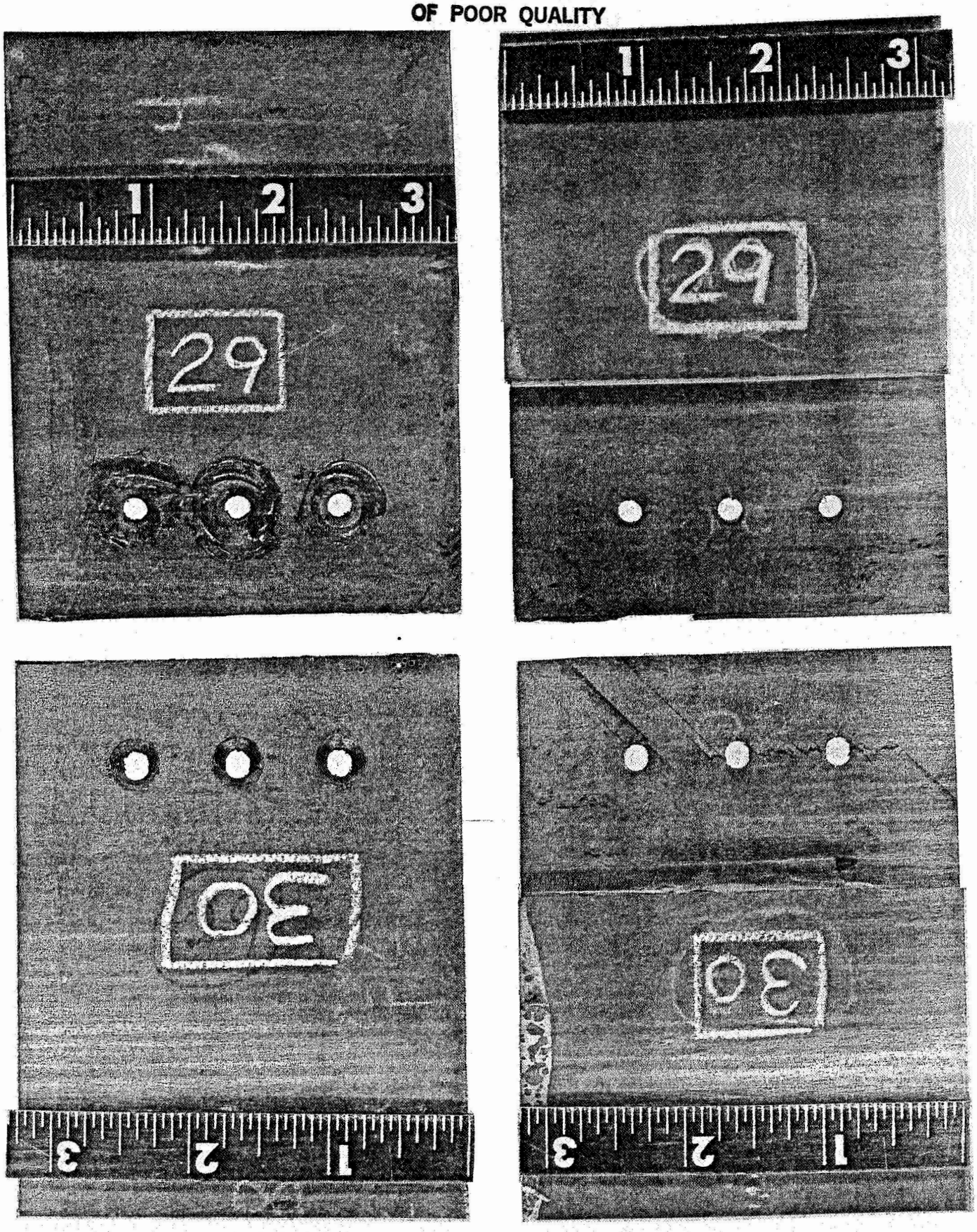


Figure 3-35: Failure of a Sealed Joint Specimen Tested Statically at -65°F.

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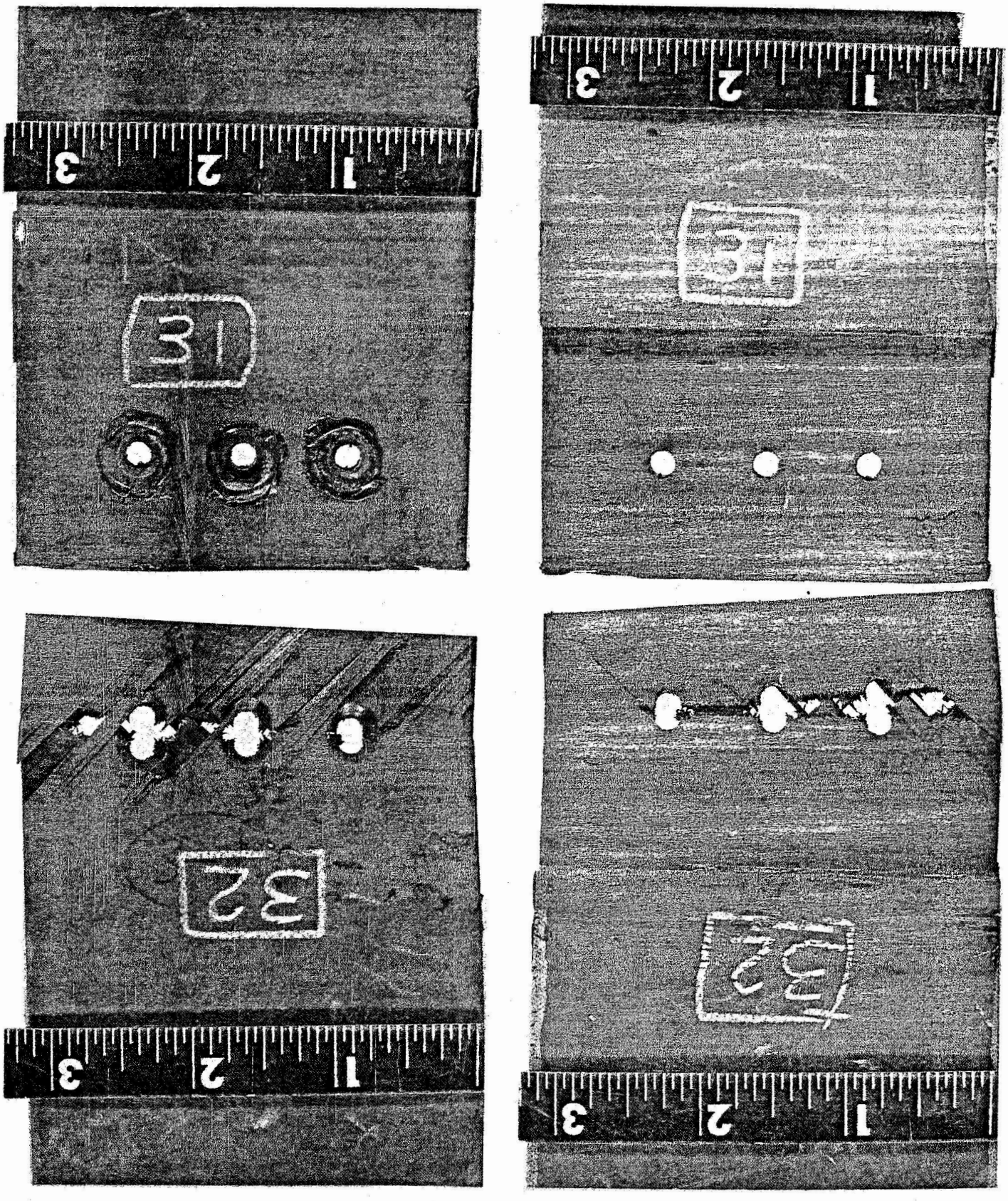


Figure 3-36: Failure of a Sealed Joint Specimen Tested Statically at -65°F.

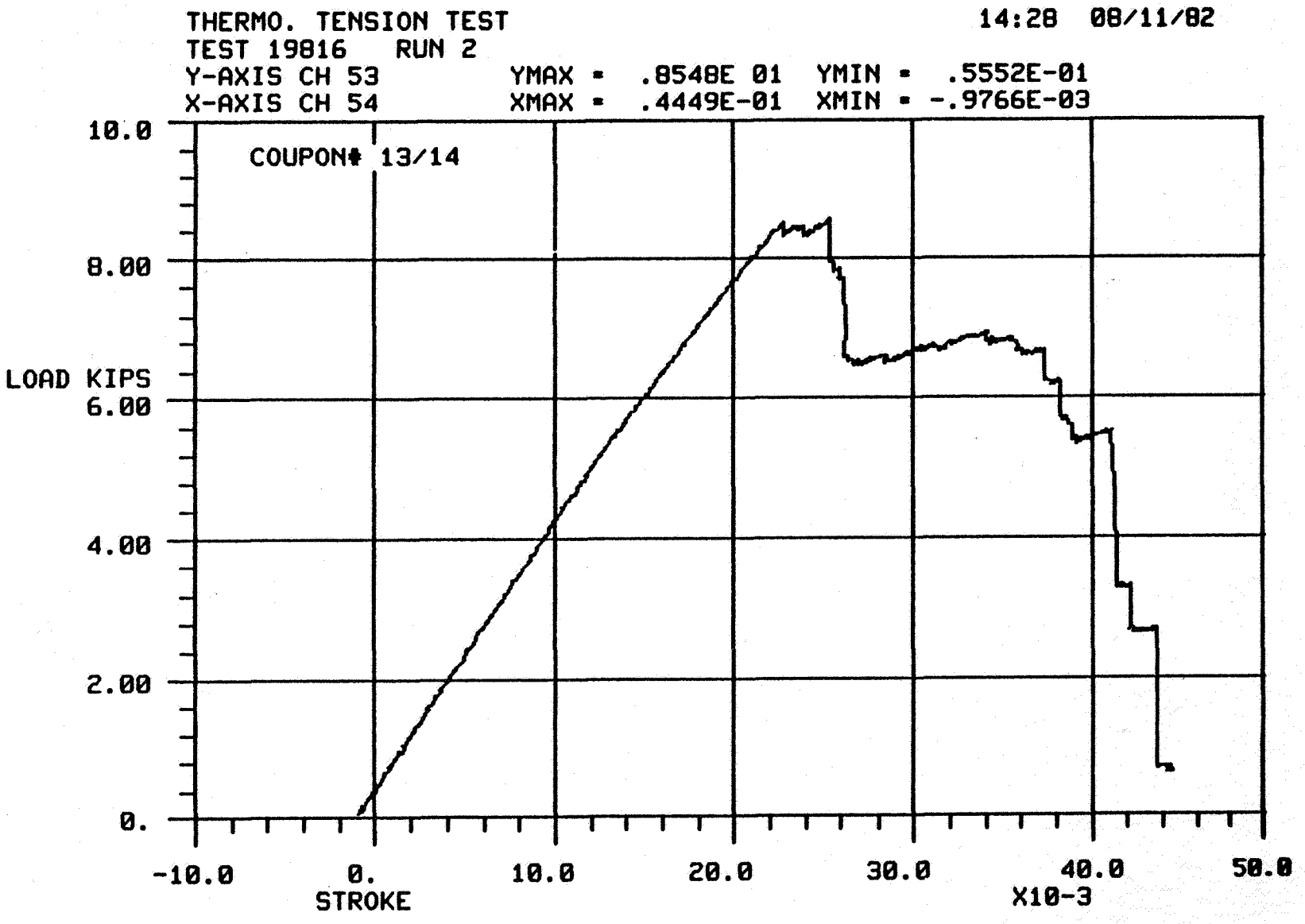


Figure 3-37: Load-Stroke Curve for Bonded Coupon 13/14 at -65°F.

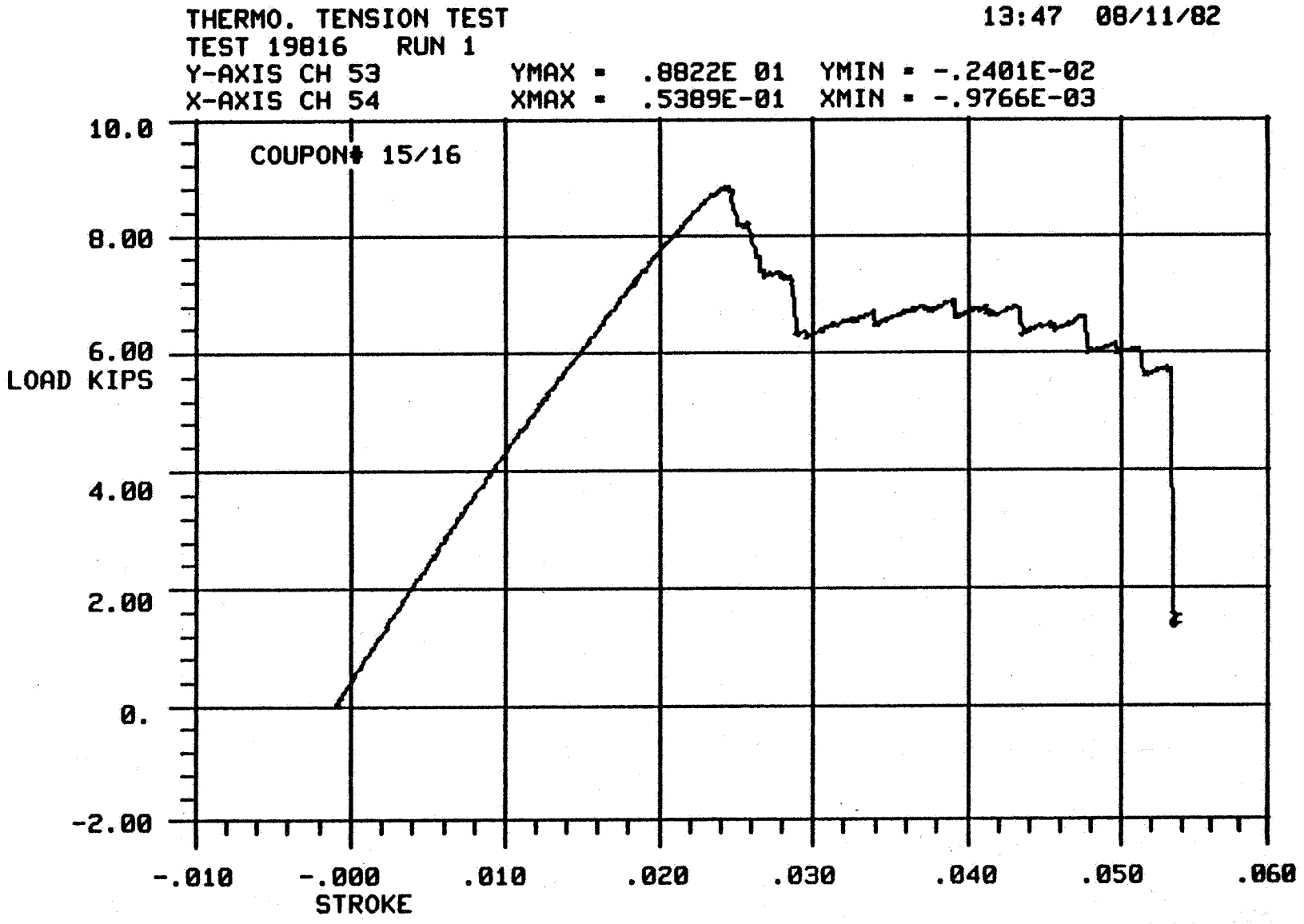


Figure 3-38: Load-Stroke Curve for Bonded Coupon 15/16 at -65°F.

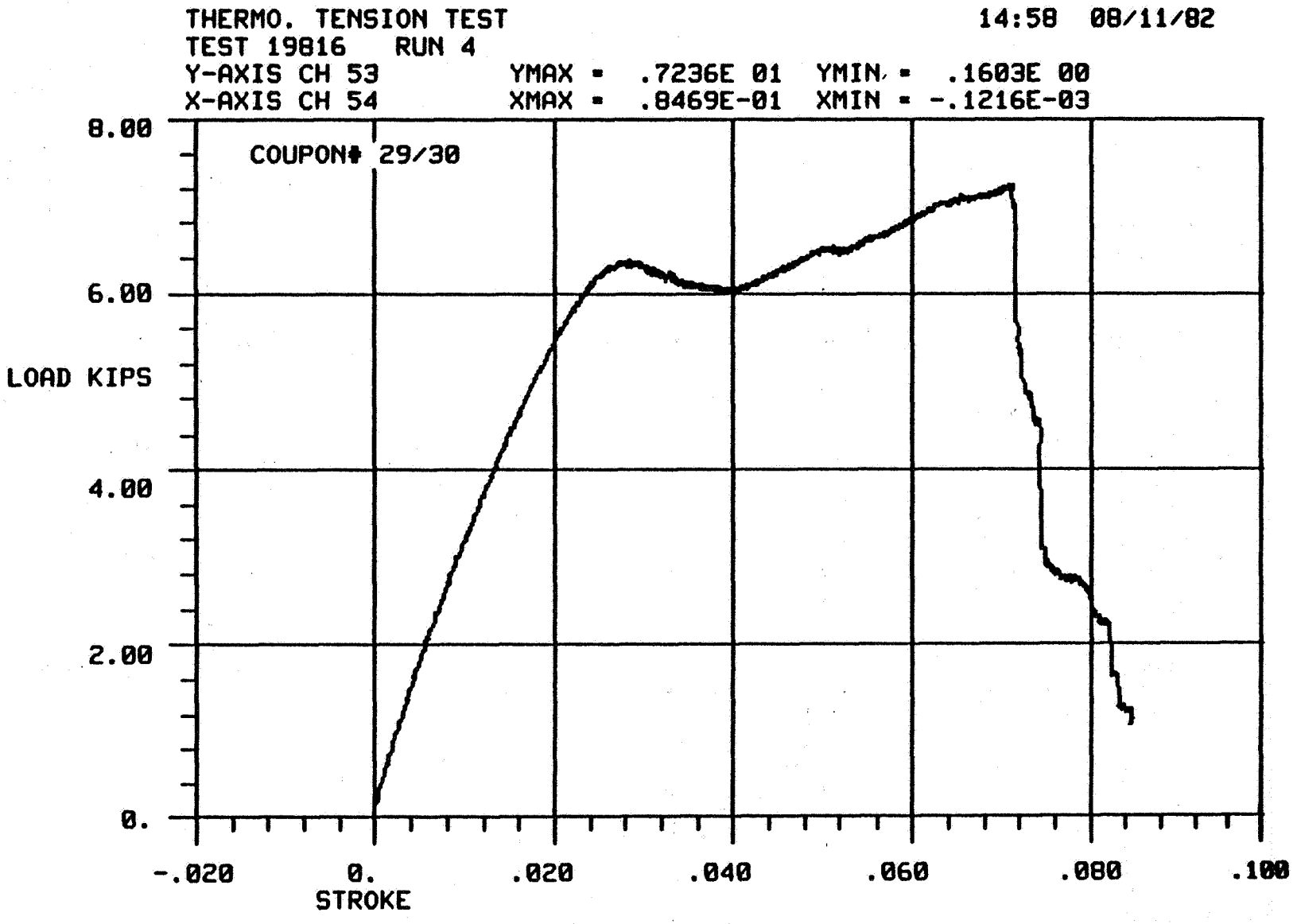


Figure 3-39: Load-Stroke Curve for Sealed Coupon 29/30 at -65°F.

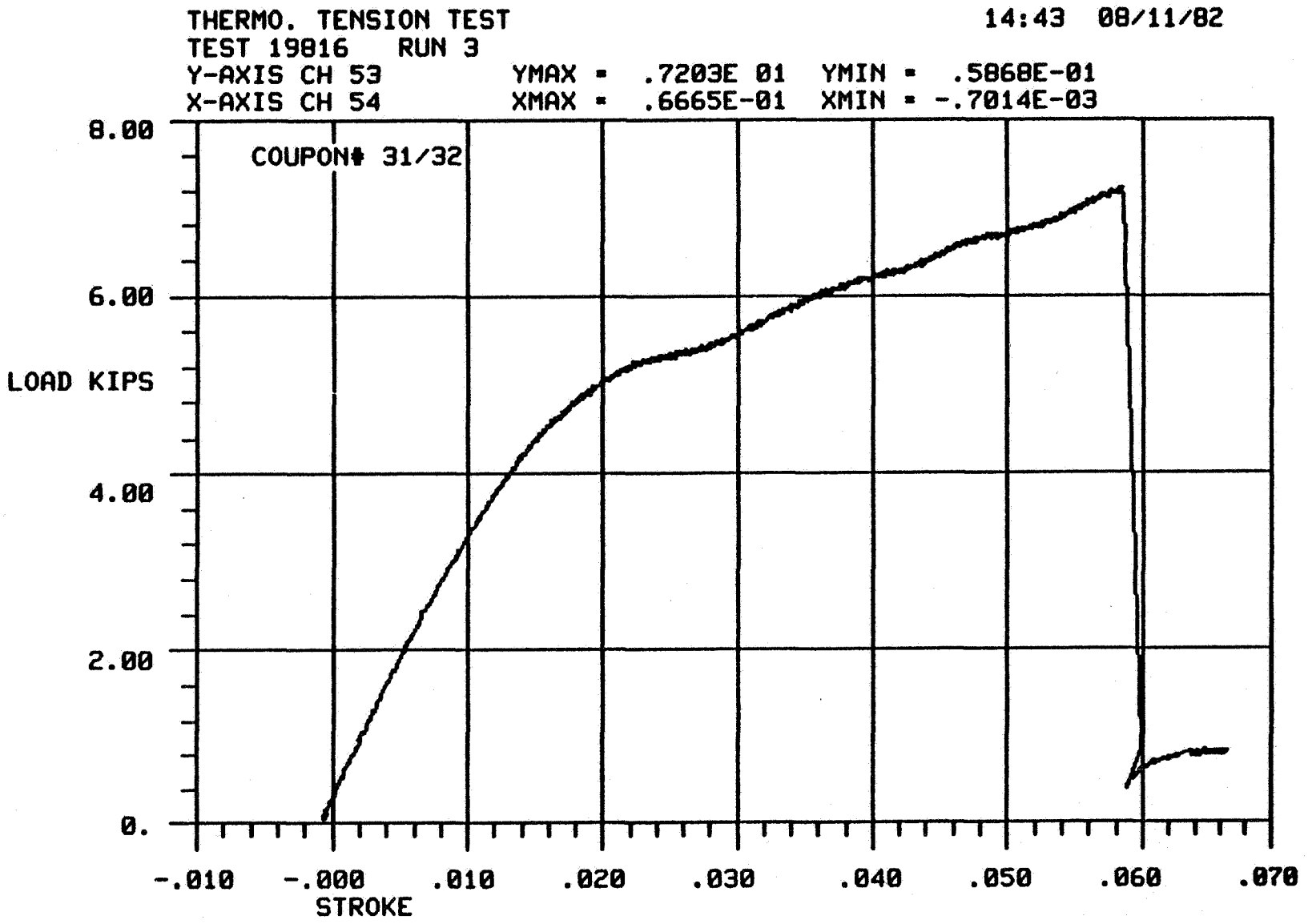


Figure 3-40: Load-Stroke Curve for Sealed Coupon 31/32 at -65°F.

SECTION 4
DESIGN DATA TESTS

4.0 INTRODUCTION

This section contains the results of tests conducted on ETR C-1-82 - Design Data Tests. Table 4-1 contains a general outline of most of the work performed on the baseline resin composite AS4/3502 and a toughened resin composite AS4/2220-1. Laminate Q. A. and processing data for the various panels is contained in Appendix B.1.

4.1 CROSSPLIED LAMINATE TENSION TESTS

Unnotched room temperature dry, unnotched -65°F dry, 1/4 in., and 1/2 in. diameter open hole room temperature dry tension tests were conducted on 1/4 in. thick by 2 in. wide coupons as described in Tables 4.2 and 4.3 and shown geometrically in Figure 4-1. No tabs were bonded to the specimens because gripping Lexan tabs 2 x 3 1/2 in. were placed in the specimen end area with 80 - 120 grit open mesh sanding cloth between the Lexan and the specimen to improve frictional load transfer. Three-and-one-half inch wide hydraulic grips were used for all notched tests, but their maximum capacity was 50,000 lbs.; therefore they could not be used for the unnotched tests. Figure 4-2 shows the test setup for notched specimens and a typical through-the-hole failure. All of the notched specimens failed through the notch. All notched specimens had a single axial strain gage mounted as shown in Figure 4-2.

Unnotched specimens were tested in a 120 kip static test machine in wedge type grips. The same lexan/sanding cloth grip tab arrangement was used. This proved unsatisfactory because of slippage problems, and generally once a slip occurred regripping was impossible. Future unnotched specimens

TABLE 4.1 - DESCRIPTION OF STATIC TESTS

Laminate Orientation	Type of Test	Size LxWxt (in.)	Impact Damage	Hole Dia. (In.)	No. of Tests			Instrumentation
					-65°F D	75°F D	180°F W ①	
$(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$	Tension	14 x 2 x .2592			3	3		Extensometer
$(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$	Tension	14 x 2 x .2592		.25		3		1 Axial Gage
$(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$	Tension	14 x 2 x .2592		.50		3		1 Axial Gage
$(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$	Compression	12 x 5 x .2592				3	3	2 Axial Gages B/B ②
$(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$	Compression	12 x 5 x .2592		1.00		3		2 Axial Gages B/B
$(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$	Compression	12 x 5 x .2592	Barely Visible ③			6 ③		2 Axial Gages B/B
$(\pm 45)_{3S}$	Tension	10.5 x 1 x .0648				5		1 T Gage
0_{12}	Tension	10.5 x 1 x .0648				5		1 T Gage
90_{12}	Sand. Beam	22 x 1 x .0648				5		1 Axial Gage
0_{12}	D C Beam	8 x 5 x .0648				3		Head Deflection
$(\pm 30_2\ 90\ \overline{90})_S$	Edge Delam.	10 x 1.5 x .0594				5		Extensometer
$(\pm 35\ 0\ 90)_S$	Edge Delam.	10 x 1.5 x .0432				5		Extensometer
				TOTALS	3	49		3 = 55 Per Material

① Wet = 45 day immersion in water @ 160°F

② B/B = Gages mounted back-to-back

③ 2 Impact Levels, 3 coupons each

MATERIALS: AS4/2220-1
AS4/3502

TABLE 4.2 - AS4/3502 TENSION TEST DATA

Laminate Orientation: $(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$

Laminate Resin Content: Panel #15 Resin Content = 35.1%, Panel #16 Resin Content = 35.1%, Panel #22 Resin Content = 32.2%

Coupon Id.	Test Type and Condition	Thickness (in.)	Width (in.)	Impact Area ($in.^2$) or Hole Dia. (in.)	Failure Load (kip)	Failure ② Stress (ksi)	Failure Strain (μin./in.)	Modulus (msi)
15 – 5 ①	Unnotched	0.263	2.007	–	60.10	113.86	11100	10.34
15 – 6 ①	at 75°F	0.260	2.006	–	64.20	123.23	12900	10.00
22 – 8	Dry	0.268	1.995	–	54.10	101.30	9650	10.07
Average					59.47	112.80	11217	10.14
22 – 5 ①	Unnotched	0.274	1.994	–	54.30	99.39	8700	10.43 ③
22 – 6	at -65°F	0.271	1.993	–	52.90	97.91	9200	10.53
22 – 7	Dry	0.268	1.995	–	55.90	104.55	9400	10.17
Average					54.37	100.62	9100	10.38
15 – 7	Open Hole	0.265	2.007	0.277	31.43	59.20	6220	9.72
15 – 8	at 75°F	0.258	2.005	0.254	32.28	62.44	6028	10.33
16 – 5	Dry	0.262	2.005	0.253	32.79	62.41	5866	10.28
Average				0.261	32.18	61.35	6038	10.11
16 – 6	Open Hole	0.254	2.016	0.507	24.90	48.64	4782	10.11
16 – 7	at 75°F	0.260	2.006	0.508	26.74	51.25	4858	10.68
16 – 8	Dry	0.253	2.002	0.516	25.38	50.16	4868	10.47
Average				0.510	25.67	50.02	4836	10.42

① Specimen delaminated before failure.

② Gross area stress.

③ Specimen slipped in the grip and was retested. Modulus from first test reported.

TABLE 4.3 - AS4/2220-1 TENSION TEST DATA

Laminate Orientation: $(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$

Laminate Resin Content: Panel #34 Resin Content = 34.5%, Panel #35 Resin Content = 35.0%, Panel #36 Resin Content = 35.7%

Coupon Id.	Test Type and Condition	Thickness (in.)	Width (in.)	Impact Area ($in.^2$) or Hole Dia. (in.)	Failure Load (kip)	Failure ③ Stress (ksi)	Failure Strain (μin./in.)	Modulus (msi)
35 – 3 ①	Unnotched	0.263	2.002	–	72.40	137.51	12900	10.43
35 – 4 ①	at 75°F	0.265	2.002	–	②	②	②	10.00 ④
36 – 1 ①	Dry	0.270	2.000	–	73.00	135.19	15200	9.61
Average					72.70	136.35	14050	10.01
36 – 2	Unnotched	0.268	2.002	–	72.20	134.57	12700	10.17 ④
36 – 3	at -65°F	0.267	2.000	–	72.60	135.96	12950	10.40
36 – 4	Dry	0.267	2.000	–	71.30	133.67	11800	⑤
Average					72.03	134.73	12483	10.29
34 – 1	Open Hole	0.271	2.003	0.249	40.42	74.46	7999	9.33
34 – 2	at 75°F	0.271	2.003	0.249	40.39	74.41	7750	9.57
34 – 3	Dry	0.268	2.003	0.250	37.44	69.74	7261	9.53
Average				0.249	39.42	72.87	7670	9.48
34 – 4	Open Hole	0.274	2.003	0.498	32.67	59.52	6298	9.80
35 – 1	at 75°F	0.265	2.001	0.495	32.32	60.95	6254	9.70
35 – 2	Dry	0.265	2.003	0.515	31.55	59.43	6044	9.63
Average				0.503	32.18	59.97	6199	9.71

① Specimen delaminated before failure.

② Specimen not tested to failure.

③ Gross area stress.

④ Specimen slipped in the grip and was retested. Modulus from first test reported.

⑤ Data not available.

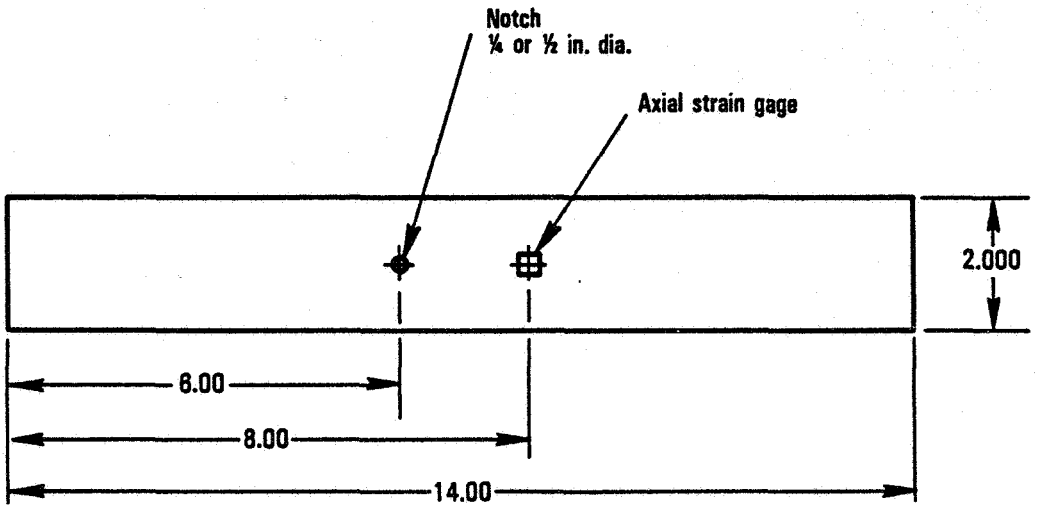


Figure 4-1: Inplane Tension Corssplied Laminate Specimen Geometry

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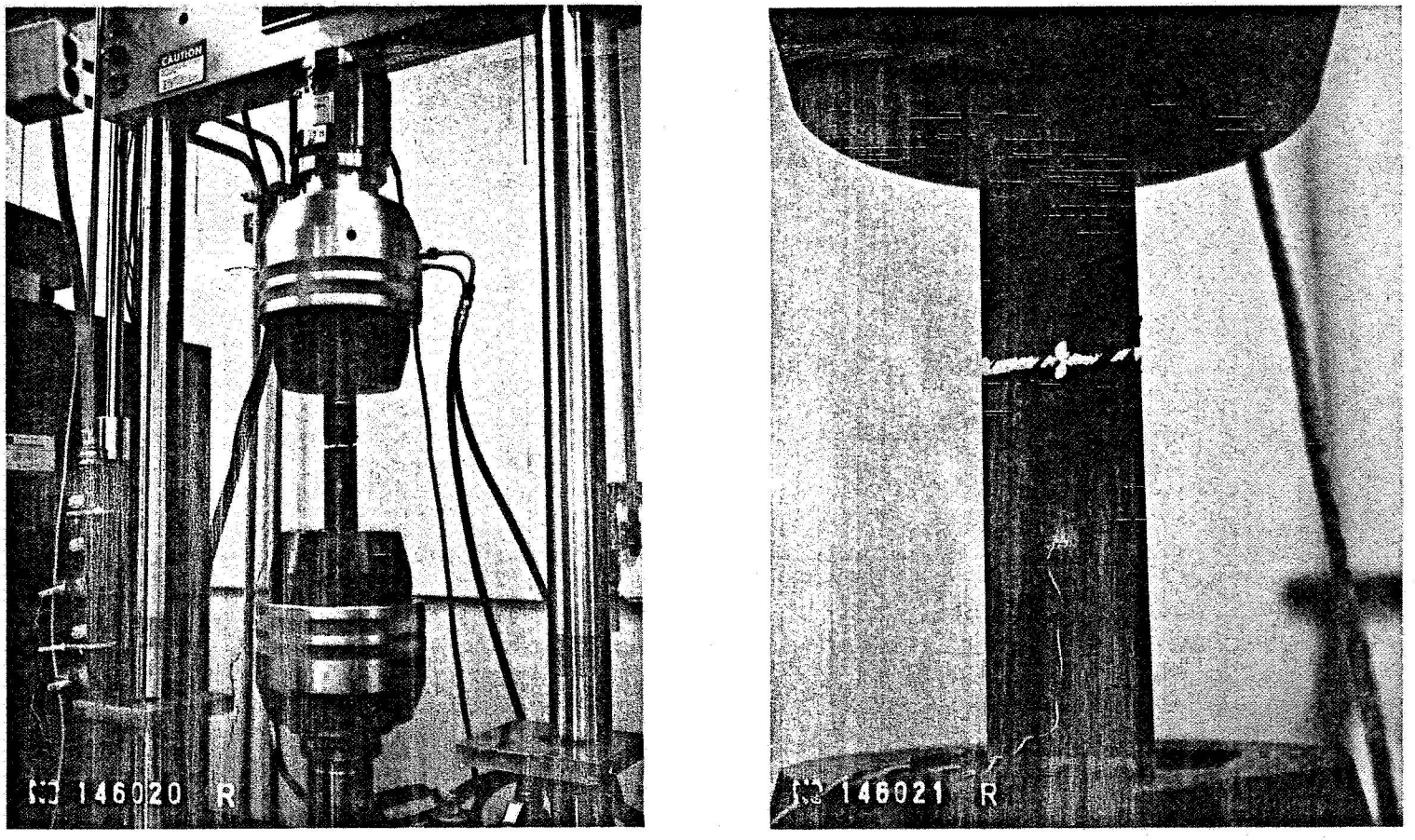


Figure 4-2: Notched Tensile Test Setup and Specimen Failure Mode

should have bonded tabs. All unnotched specimens used an extensometer for strain measurement rather than the strain gages used on all notched tests. Near failure on the unnotched specimens, edge delaminations were noted which may have introduced errors in the recorded ultimate strain values. Strain gages on these specimens are recommended for any future testing. Typical unnotched failures are shown in Figure 4-3 for both AS4/3502 and AS4/2220-1. All failures were in the center test section, not in the grip area. Loading rate on all tests was 0.05 in/min.

The AS4/3502 tension test data are reported in Table 4-2. Average strain to failure of the unnotched room temperature dry coupons is much lower than the 1.3% expected of the AS4 fiber. The 19% reduction in strain to failure from room temperature to -65°F is somewhat higher than expected. The modulus values are as expected and are close to those predicted by laminate analysis.

The AS4/2220-1 tension test data are reported in Table 4-3. Average strain to failure of the unnotched room temperature dry coupons is much higher than that of the AS4/3502 coupons for the same test conditon and higher than the 1.3% expected of the AS4 fiber. The 11% reduction in strain to failure from room temperature to -65°F is as expected and is similar to the reduction experienced with T300/5208.

The open hole tension test data for AS4/3502 and AS4/2220-1 from Tables 4.2 and 4.3 are plotted on Figure 4-4. Also included on Figure 4-4 are data from T300/5208 quasi-isotropic laminate open hole tension tests done as part of the Lockheed IRAD project. The plot of failure strain versus notch size shows that the AS4 composites have a higher strain to failure than the T300 composite. The 2220-1 resin is also shown to be tougher than the 3502 resin. It appears that with a high strain fiber and a toughened resin system a notched (1/4 in. diameter) 6000 μin./in tension design allowable is possible.

Load-strain and load-deflection curves are presented in Appendix B-2.

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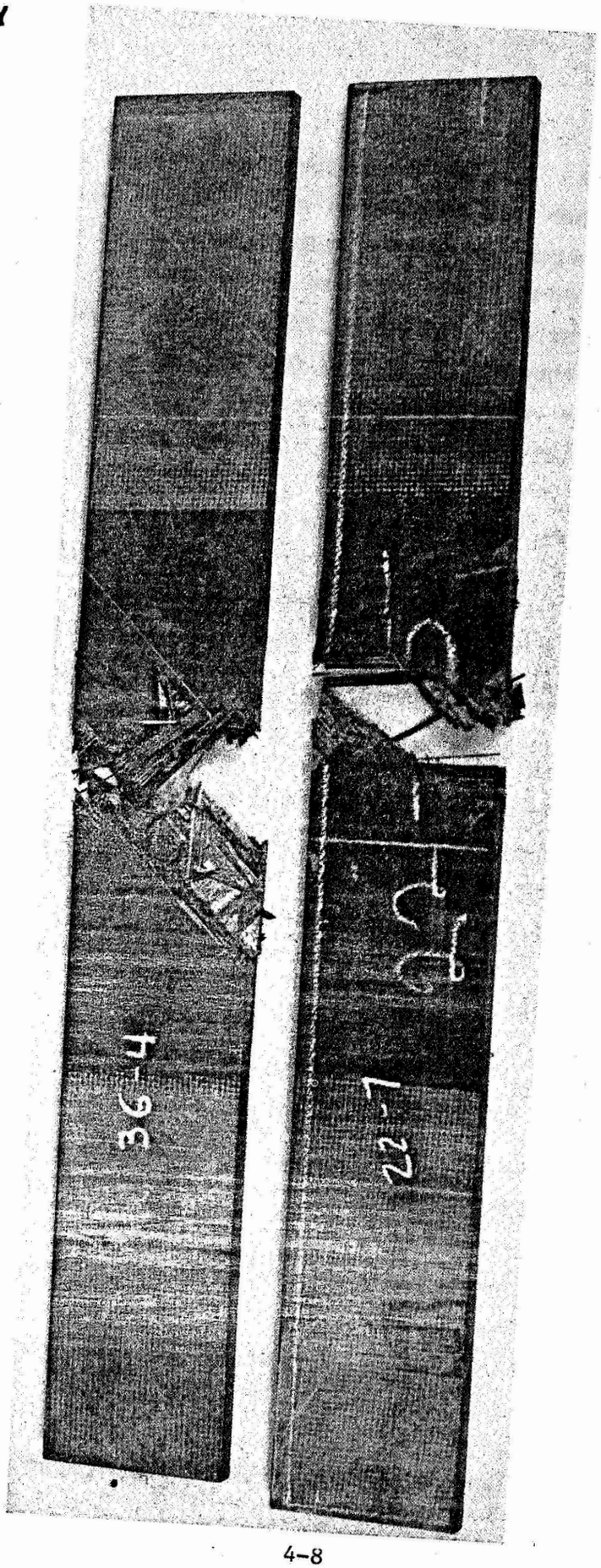


Figure 4-3: Typical Failure of Unnotched Crossplied Laminate Specimens.

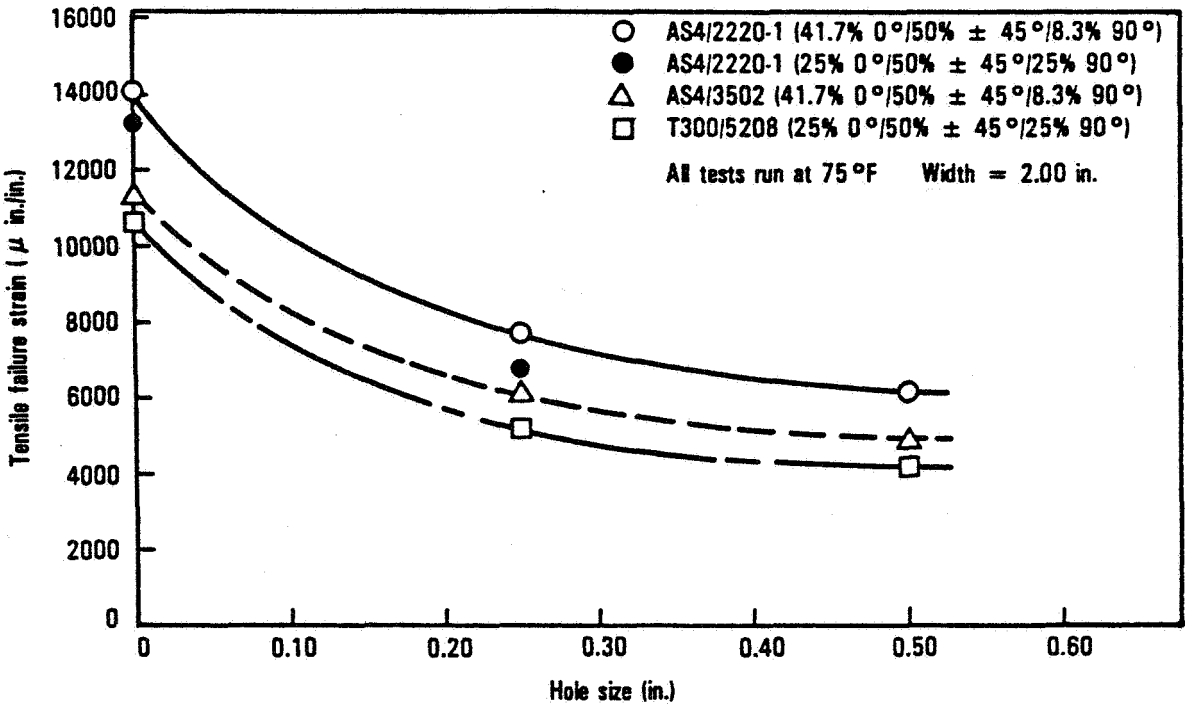


Figure 4-4: Effect of Hole Size on Tensile Failure Strain

4.2 COMPRESSION TESTS

Compression tests were conducted on specimens of both AS4/3502 and AS4/2220--1 under a variety of test conditions including: notched; impacted; unnotched and unimpacted; room temperature dry; 180°F wet; widths of 2, 3.5 and 5 inches; and two types of test fixtures. All specimens were from laminates of the (41.7% 0°/50.0% ±45°/8.3% 90°) configuration. Data are summarized in Table 4.4 for the AS4/3502 and in Table 4.5 for the AS4/2220-1. Load strain curves and laboratory notes are contained in Appendix B-3.

Standard specimen geometry was 5 inches wide by 12 inches long as shown in Section 2.3. Notched specimens had a 1.00 inch diameter hole located in the specimen center. Strain gages were located 1 inch from the side edge and 2 inches from the top edge mounted back-to-back. Standard test procedure was to orient the specimen in the test fixture such that the strain gages were located in the upper right hand corner facing the operator. The test fixture was indexed so that the top plate was installed in the same direction each time, and the fixture had a set orientation in the loading machine. Specific instances where deviation from this procedure were made are noted in the laboratory notes. Some specimens exhibited a deviation between the front (gage A) and back (gage B) strain gages, so most specimens were initially loaded to about 5 percent of anticipated failure load to preview the strain gage tracking then unloaded. If they began deviating the specimen was reversed in the fixture so that gage B now appeared on the upper left side of the fixture. In some cases this improved tracking, in others it did not help.

Trial impact tests were performed to select impact energies for compression tests. Impacting was done in the same manner as in Section 2 with the same equipment. All trial impacts were done on a 47 ply AS4/3502 panel #14. Four hits were made on each 7 x 25 panel. Photographs of the front and back surface damage are shown for typical hits in Figures 4-5 through 4-14. After impact C-scans were made to determine the extent of damage. These

TABLE 4.4. AS4/3502 COMPRESSION TEST DATA

Laminate Orientation: $(\pm 45\ 90_2(\pm 45\ 0_2)_5)_S$

Laminate Resin Content: Panel #15 Resin Content = 35.1%, Panel #16 Resin Content = 35.1%, Panel #22 Resin Content = 32.2%, Panel #104 Resin Content = 31.4%

Coupon ID	Test Type and Cond.	Thickness (in.)	Width (in.)	Impact Area ($in.^2$) or Hole Dia. (in.)	Failure Load (kip)	Failure Stress (ksi) (3)	Failure Strain (μin./in.)	Modulus (msi) (4)
104-2A (1)	Unnotched	0.260	3.493	-	-65.08	-71.78	-8760	8.44
104-2B (1)	at 75°F Dry	0.270	3.493	-	-59.98	-63.60	-7890	8.84
Avg.					-62.53	-67.69	-8325	8.64
15-4B	Open Hole	0.263	5.003	0.999	-51.44	-39.07	-4594	8.35
16-1A	at 75°F Dry	0.274	5.002	0.993	-48.80	-35.56	-4304	8.16
16-1B		0.274	5.001	0.998	-52.69	-38.44	-4899	7.66
Avg.				0.997	-50.98	-37.69	-4599	8.06
15-1A (2)	20 ft-lb.	0.268	5.013	2.30	-45.79	-34.07	-3937	8.56
15-2A	Impacted at	0.259	5.015	2.35	-44.80	-34.51	-3868	8.96
15-4A	75°F Dry	0.275	5.003	2.85	-46.17	-33.56	-4141	8.14
22-1A (2)		0.269	4.999	3.20	-43.67	-32.49	-4082	8.20
22-1B (2)		0.269	4.999	2.85	-46.09	-34.32	-4024	8.94
Avg.				2.71	-45.30	-33.79	-4010	8.56
15-2B	30 ft-lb.	0.273	5.014	3.15	-42.91	-31.81	-3741	9.16
15-3A	Impacted at	0.269	5.012	4.90	-41.09	-30.02	-3392	8.52
15-3B	75°F Dry	0.275	5.013	4.20	-39.29	-28.49	-3392	8.32
Avg.				4.08	-41.10	-30.11	-3508	8.67

TABLE 4.4. AS4/3502 COMPRESSION TEST DATA (Continued)

Coupon ID	Test Type and Cond.	Thickness (in.)	Width (in.)	Impact Area ($in.^2$) or Hole Area (in.)	Failure Load (kip)	Failure Stress (ksi)	Failure Strain (μin./in.)	Modulus (msi)
16-3B	Unnotched ⑤	0.275	5.005	-	-93.36	-67.94	-7377	10.55
16-4A	at 180°F Wet	0.270	5.004	-	-82.46	-61.12	-7191	9.04
16-4B		0.275	5.004	-	-72.96	-53.02	-6627	8.44
Avg.					-82.93	-60.69	-7065	9.34
16-2A ①	Unnotched	0.268	5.006	-	-98.75	-73.65	-8930	8.80
16-2B ①	at 75°F Dry	0.262	5.001	-	-93.10	-75.83	-9182	9.02
16-3A ①		0.264	5.003	-	-93.43	-70.83	-8240	9.76
Avg.					-97.09	-73.44	-8784	9.19
22-2-1A	Unnotched	0.262	2.002	-	-59.75	-113.81	-14314	8.54
22-2-1B	at 75°F	0.262	2.002	-	-58.89	-112.38	-13765	8.65
Avg.	Dry ⑥				-59.32	-113.10	-14040	8.60
15-2-A	Unnotched	0.251	2.005	-	-33.27	-66.17	-16707	4.28
15-2-B	at 75°F	0.254	2.001	-	-31.57	-62.17	-15289	4.32
Avg.	Dry ⑥⑦				-32.42	-64.17	-15998	4.30

① Specimen failed in the grip
② Specimen impacted with 22 ft-lb.
③ Gross area stress.
④ Tangent modulus at 2000 μin./in.
⑤ Wet = 45 day immersion in water
⑥ V-groove compression fixture
⑦ Specimens oriented at 90° (all other at 0°).

TABLE 4.5.- AS4/2220-1 COMPRESSION TEST DATA

Laminate Orientation: $(\pm 45\ 90_2(\pm 45\ 0_2)_5)_S$

Laminate Resin Content: Panel #34 Resin Content = 34.5%, Panel #35 Resin Content = 35.0%, Panel #36 Resin Content = 35.7%

Coupon Id.	Test Type and Condition	Thickness (in.)	Width (in.)	Impact Area ($in.^2$) or Hole Dia. (in.)	Failure Load (kip)	Failure ③ Stress (ksi)	Failure Strain (μin./in.)	Modulus (msi) ④
34 - 2B ①	Unnotched	0.269	3.500	—	-63.96	-67.91	-8590	9.10
34 - 3A ①	at 75°F	0.271	3.501	—	-63.44	-66.94	-8454	9.36
34 - 3B ①	Dry	0.272	3.501	—	-63.59	-66.88	-8709	9.09
Average					-63.66	-67.24	-8584	9.18
34 - 4A ②	Open Hole at	0.271	5.001	0.998	-46.80	-34.54	-3807	10.48
34 - 4B	75°F	0.271	5.001	1.000	-42.36	-31.22	-3425	9.68
35 - 1A	Dry	0.269	5.004	1.001	-48.27	-35.84	-3908	9.47
Average				1.000	-45.81	-33.87	-3713	9.88
35 - 2A		0.269	5.007	2.45	-56.16	-41.75	-4992	8.73
35 - 2B		0.271	5.007	1.75	-58.62	-43.23	-5137	8.59
35 - 3A	20 ft-lb	0.275	5.008	2.55	-52.05	-37.74	-4503	8.65
36 - 1A	Impact at	0.273	4.998	2.30	-51.12	-37.50	-4265	9.20
36 - 1B	75°F Dry	0.272	4.999	1.95	-55.54	-40.86	4989	8.39
36 - 2A		0.269	4.998	2.30	-51.89	-38.61	-4621	8.33
Average				2.22	-54.23	-39.95	-4751	8.65

TABLE 4.5. AS4/2220-1 COMPRESSION TEST DATA (Continued)

Laminate Orientation: $(\pm 45\ 90_2(\pm 45\ 0_2)_5)_S$

Laminate Resin Content: Panel #34 Resin Content = 34.5%, Panel #35 Resin Content = 35.0%, Panel #36 Resin Content = 35.7%

Coupon Id.	Test Type and Condition	Thickness (in.)	Width (in.)	Impact Area ($in.^2$) or Hole Dia. (in.)	Failure Load (kip)	Failure ③ Stress (ksi)	Failure Strain (μ in./in.)	Modulus (msi) ④
35 - 3B	30 ft-lb	0.273	5.008	5.00	-41.63	-30.45	-3603	8.75
35 - 4A	Impact at	0.275	5.008	5.30	-42.28	-30.66	-3775	8.19
35 - 4B	75°F Dry	0.276	5.009	3.70	-46.23	-33.47	-4093	8.52
Average				4.67	-43.38	-31.53	-3824	8.49
34-2-A	Unnotched 5	0.250	2.003	—	-52.70	-105.07	-13019	8.67
34-2-B	at 75°F Dry	0.252	2.008	—	-52.43	-103.49	-12584	8.83
Average					-52.57	-104.28	-12802	8.75
34 - 1A	Unnotched 6	0.269	5.004	—	-87.16	-64.75	-6280	9.52
34 - 1B	at 180°F	0.268	5.004	—	-93.39	-69.64	-7580	8.95
34 - 2A ⑦	Wet	—	—	—	—	—	—	—
Average					-90.28	-67.20	-6930	9.24

① Specimen failed in the grip.
② Specimen buckled at failure.
③ Gross area stress.
④ Tangent modulus at 2000 μin./in.
⑤ V-groove compression fixture.
⑥ Wet = 45 day immersion in water at 160°F
⑦ Specimen not machined square.

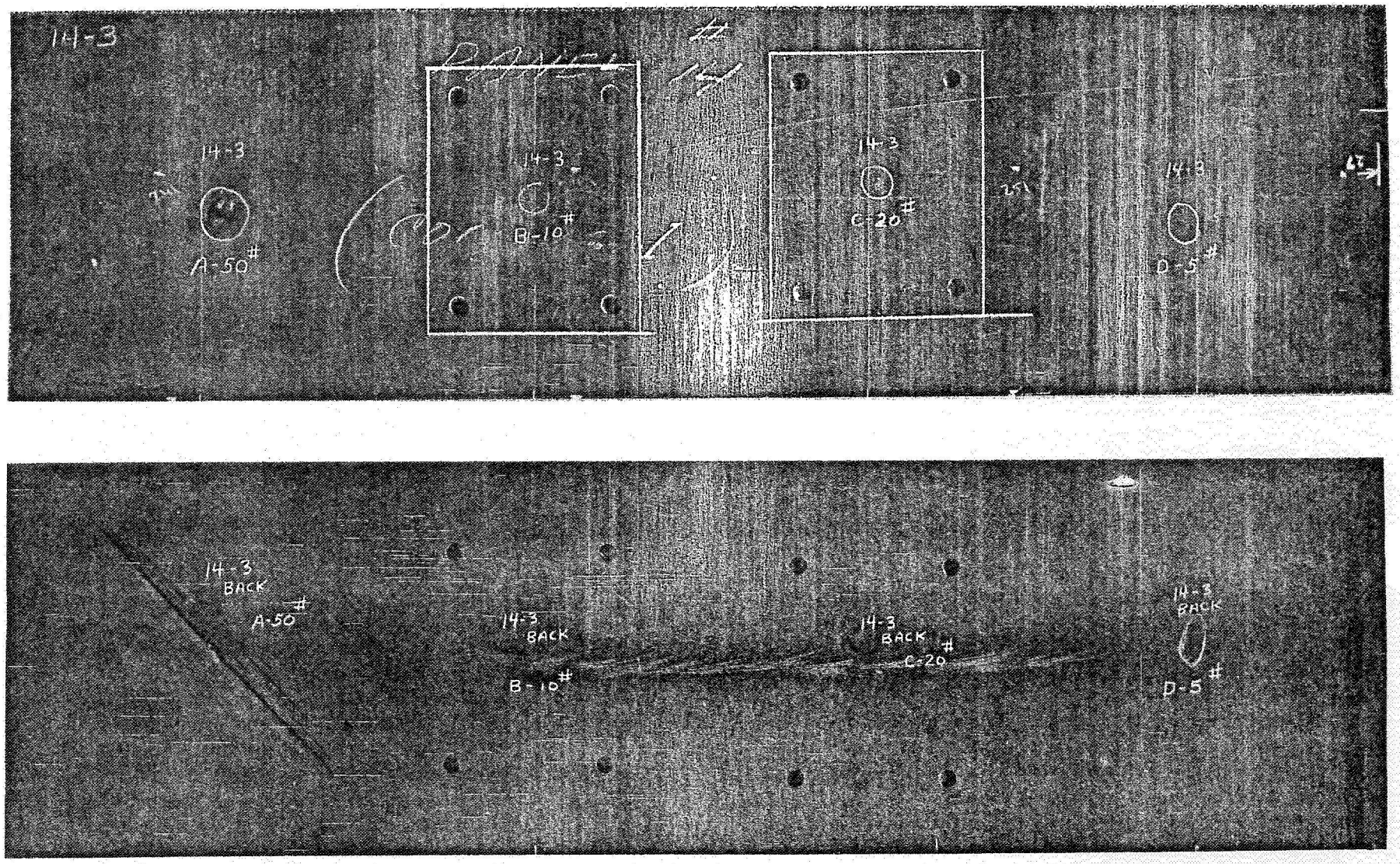
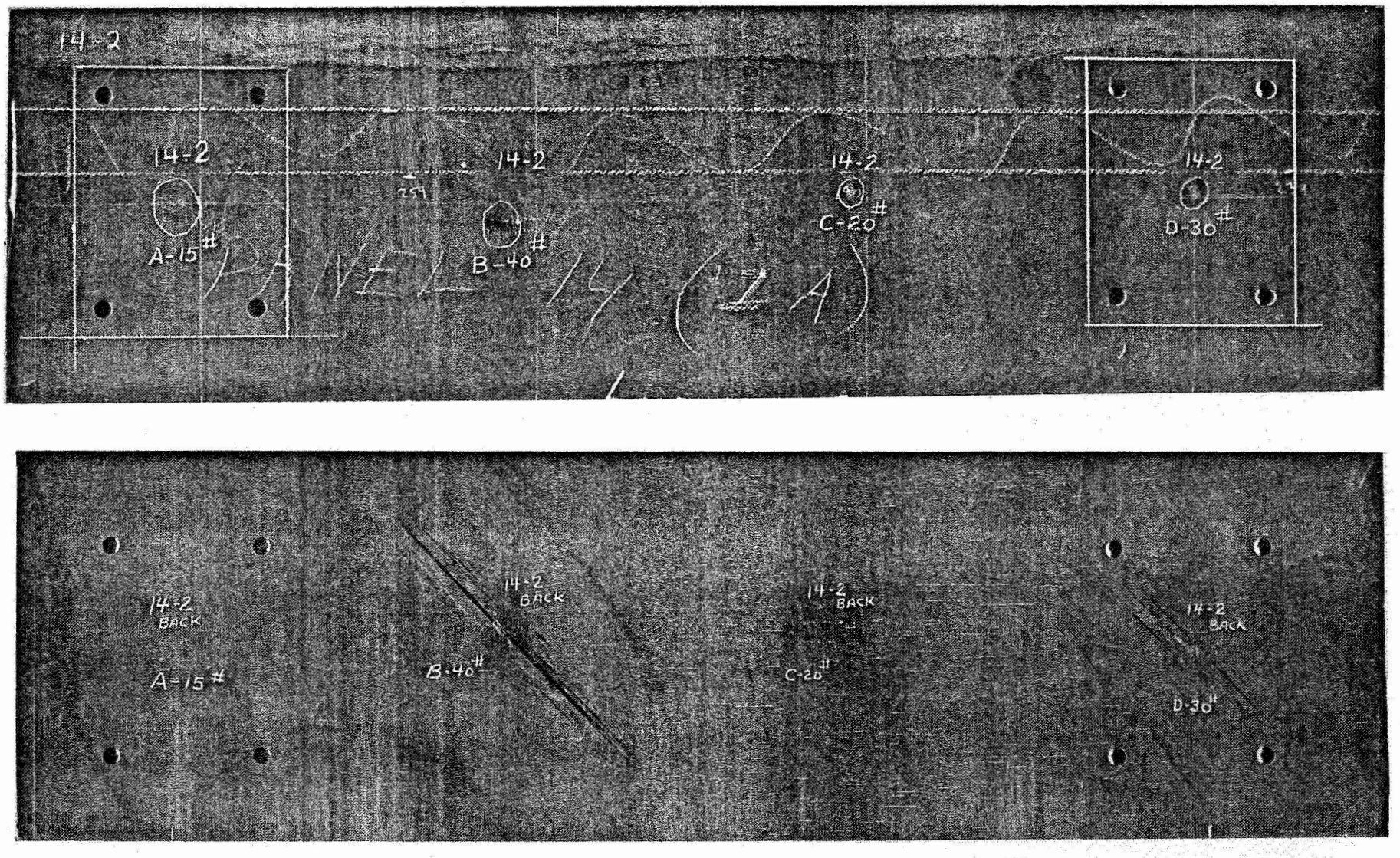


Figure 4.5: 47 Ply AS4/3502 Trial Impact Panel Showing Front and Back Surface Damage. Those Sites With Four Holes are Ones Selected for Leakage Tests. Numbers With # Indicate Impact Energy (In Ft.-Lbs.).

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Figure 4.6: Trial Impact Panel of 47 Ply AS4/3502 Showing Front and Back Surface Damage At Various Impact Energies Denoted by # (In Ft.-Lbs.). Those Sites With Four Holes Are Ones Selected For Leakage Tests.

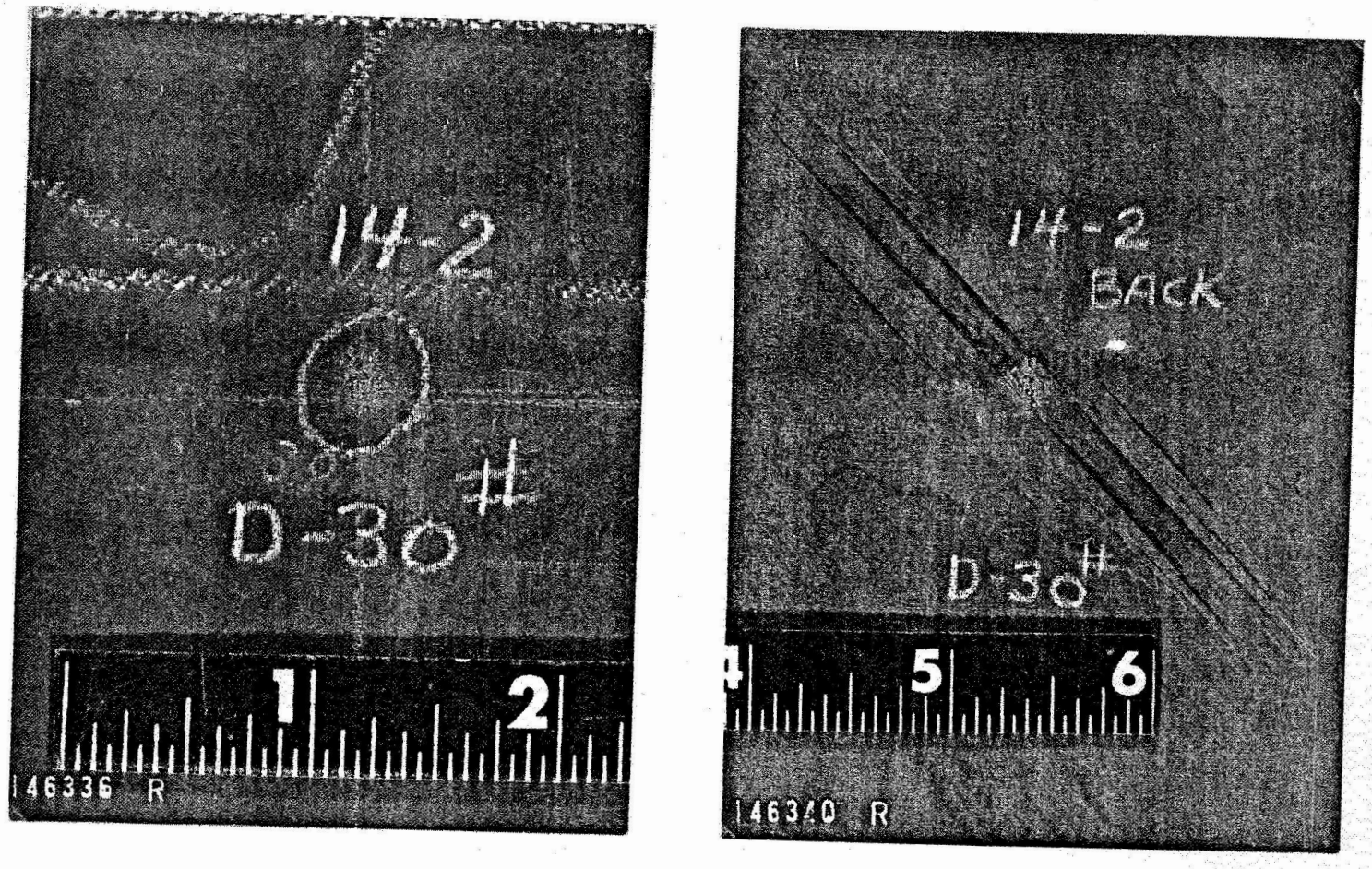


Figure 4-7: Front and Back Views of a 30 Ft.-Lb. Impact on 47-Ply AS4/3502. Scale is in Inches.

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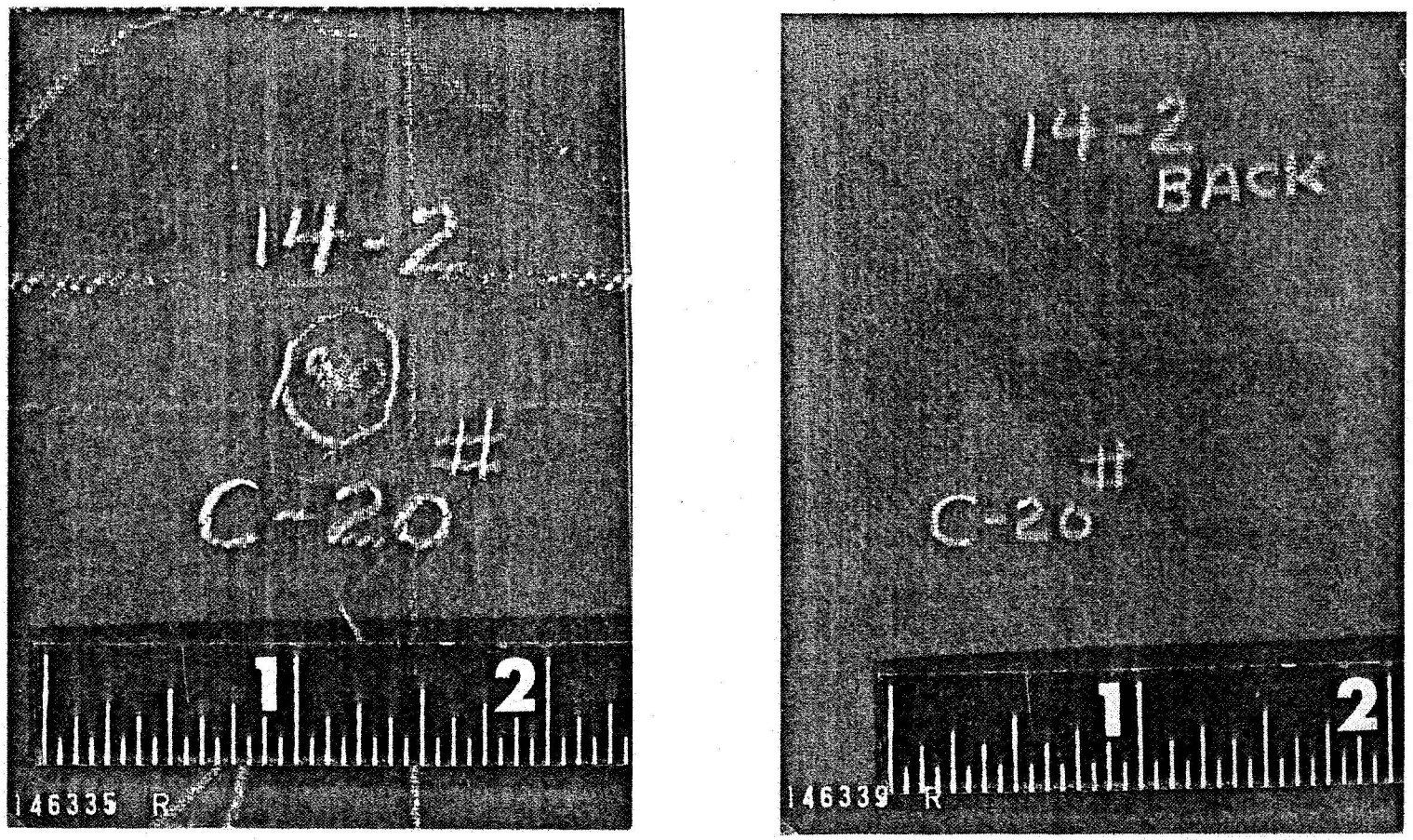


Figure 4-8: Front and Back View of a 20 Ft.-Lb. Impact on 47-Ply AS4/3502.

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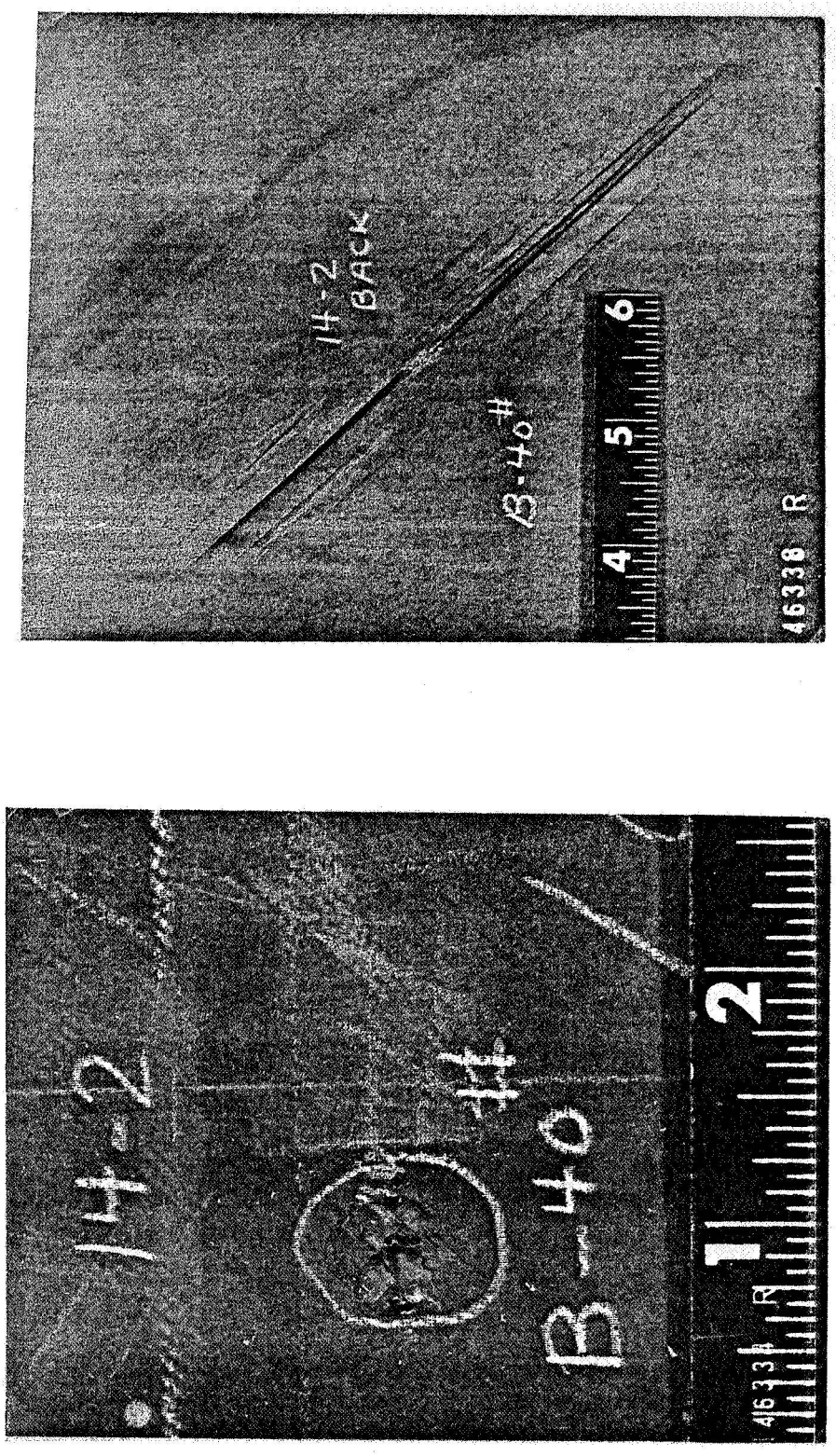


Figure 4-9: Front and Back View of a 40 Ft.· Lb. Impact on 47-Ply AS4/3502.

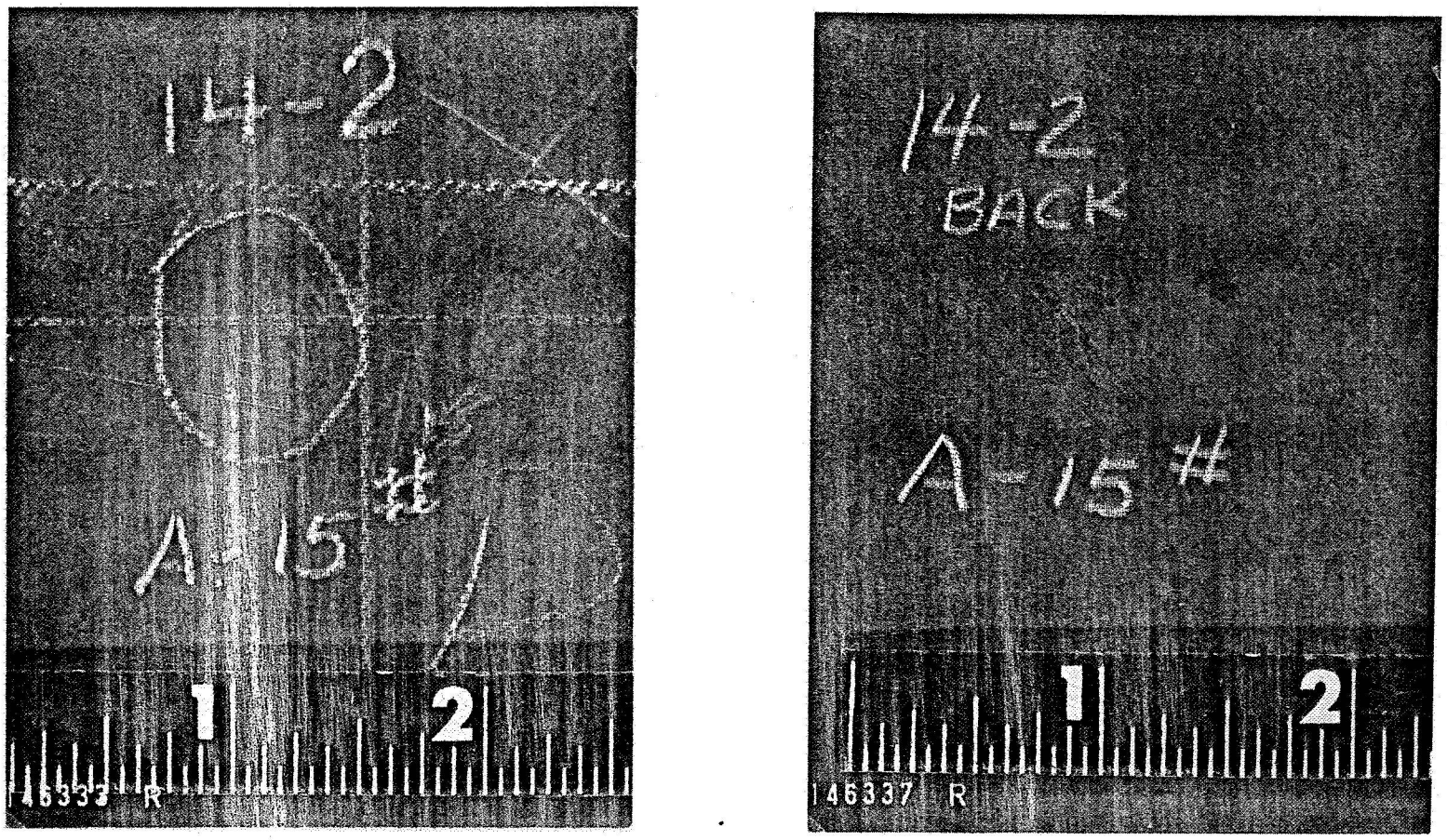


Figure 4-10: Front and Back View of a 15 Ft.-Lb. Impact On 47-Ply AS4/3502.

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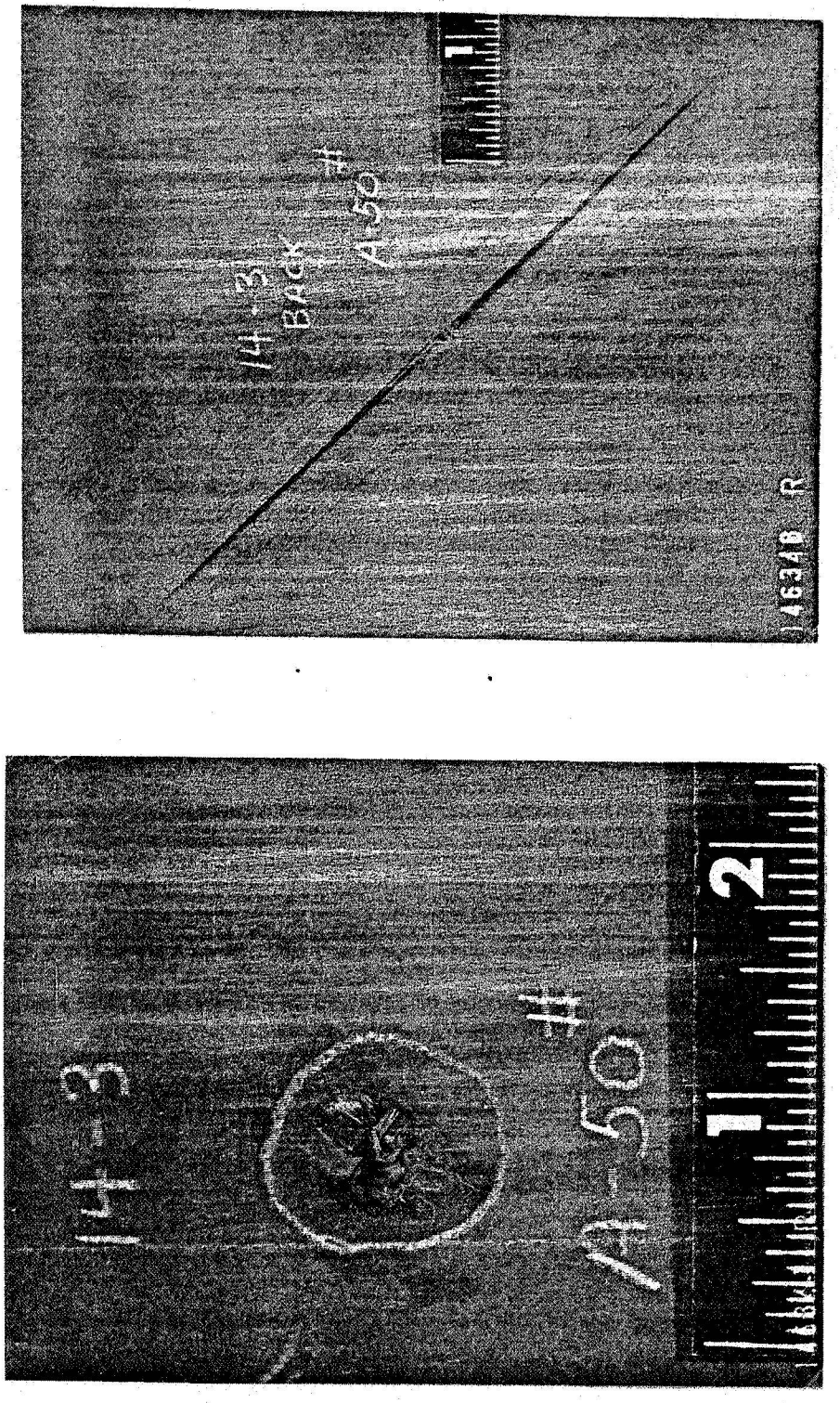


Figure 4-11: Front and Back View of a 50 Ft.-Lb. Impact on 47-Ply AS4/3502.

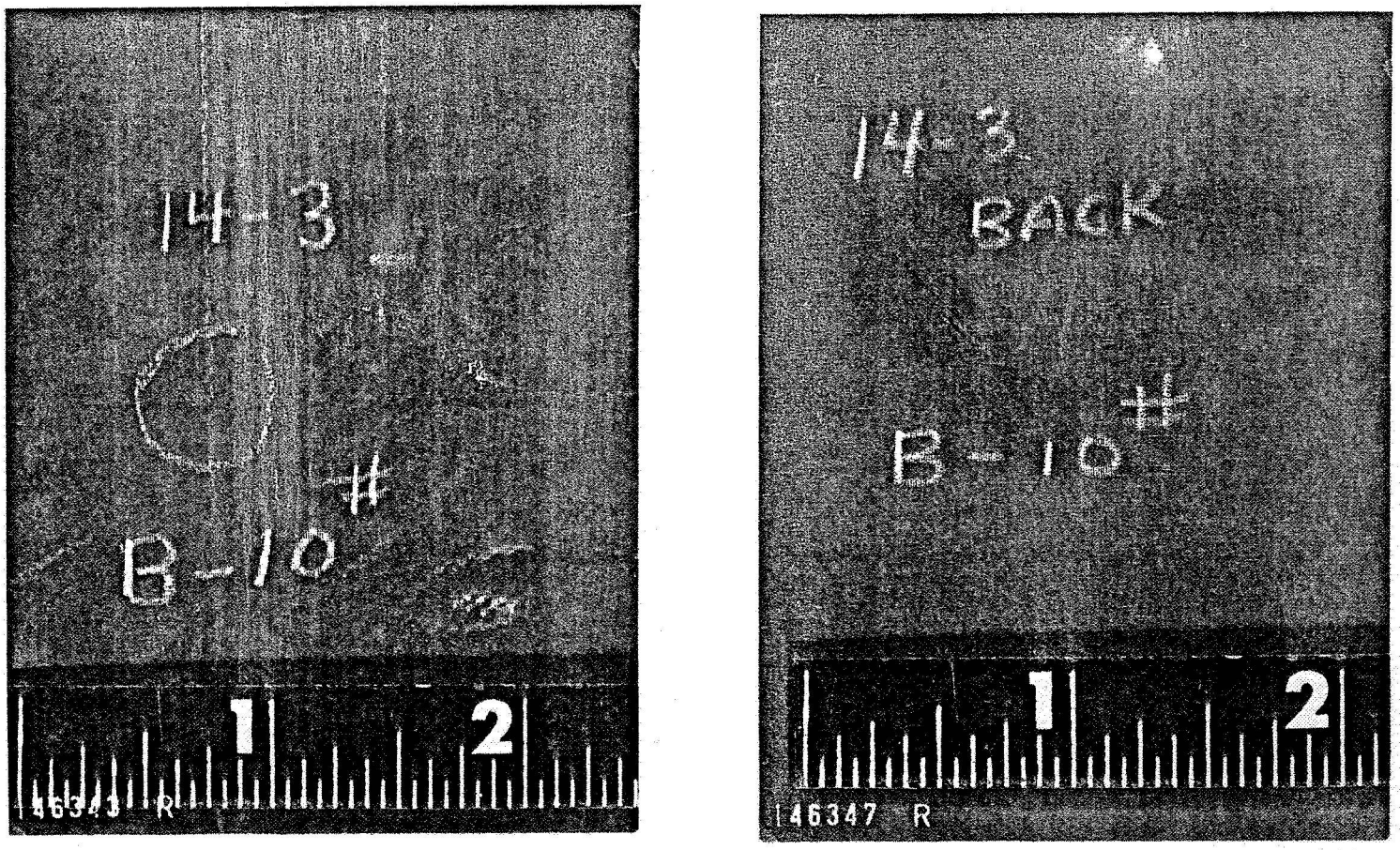


Figure 4-12: Front and Back View of a 10 Ft.-Lb. Impact on 47-Ply AS4/3502.

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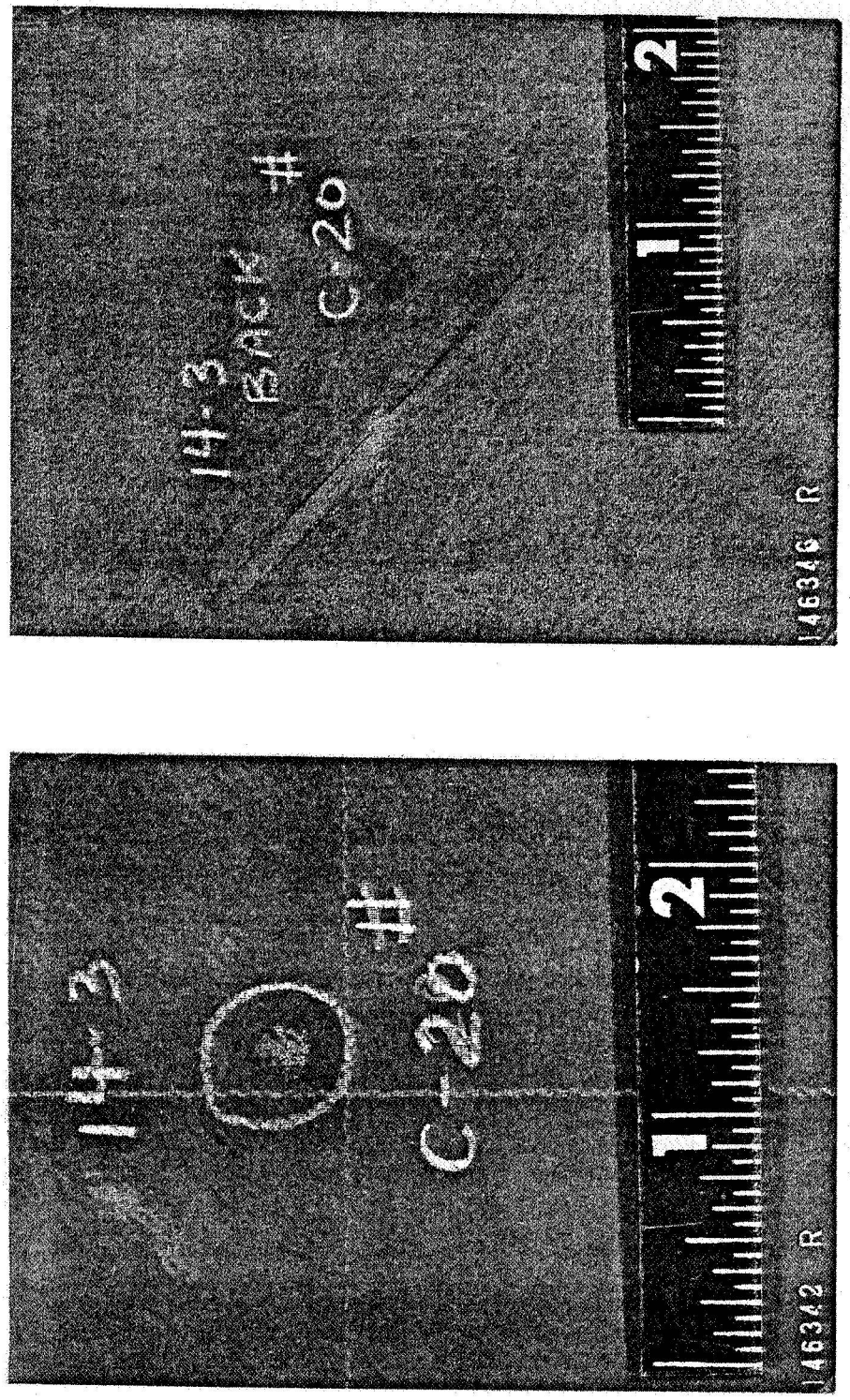
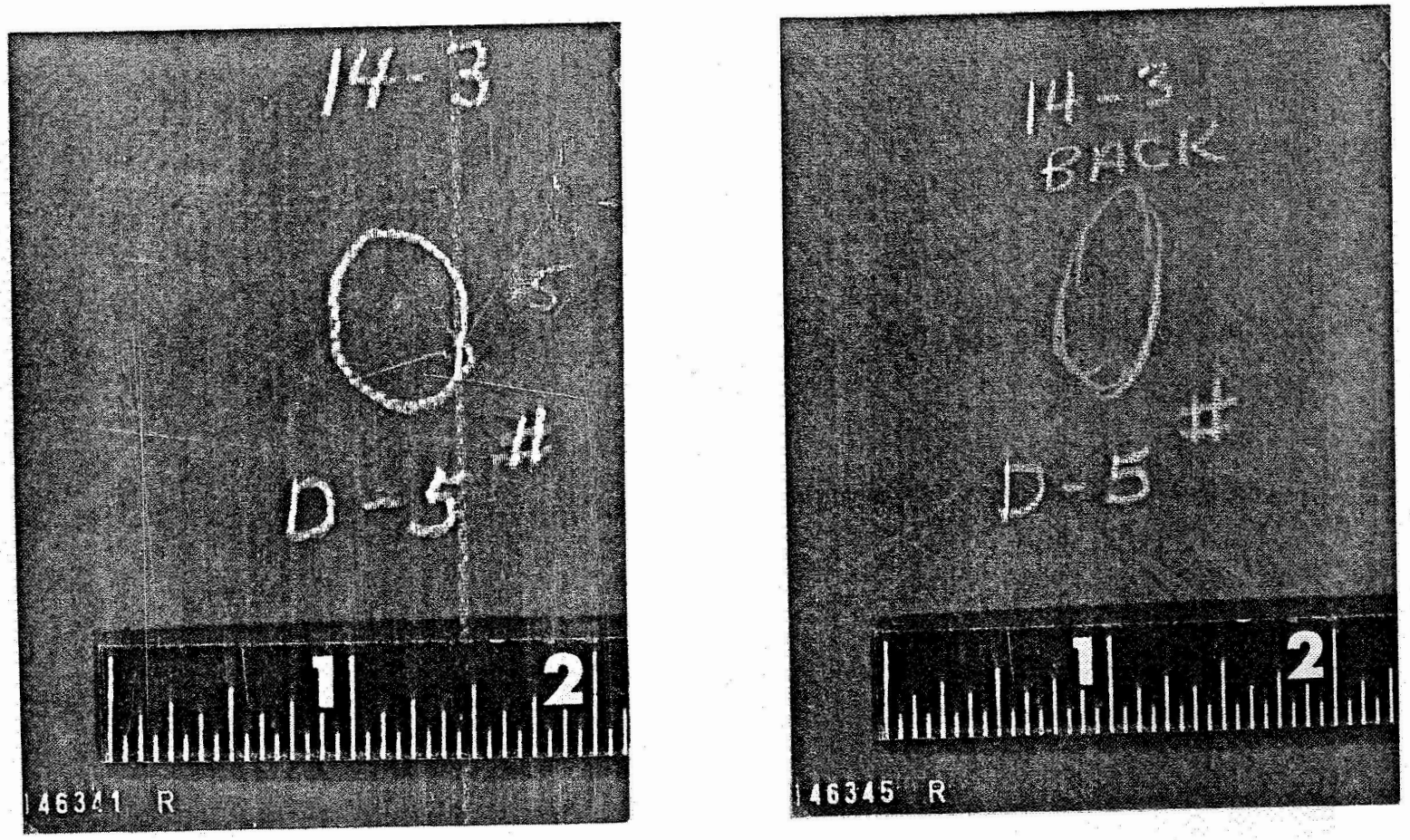


Figure 4-13: Front and Back View of a 20 Ft.-Lb. Impact on 47-Ply AS4/3502.



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Figure 4-14: Front and Back View of a 5 Ft.-Lb. Impact on 47-Ply AS4/3502.

data are listed in Table 4.6. The damage threshold is between 5 and 10 ft.-lbs. with panel penetration occurring at 40 ft.-lb.

Twenty and 30 ft.-lbs. impact energy levels were selected for compression tests. Two hits were made on each 7 x 25 panel which was subsequently out to the final 5 x 12 inch test size. C-scan results and visual observations are tabulated in Table 4.7 fOR THE AS4/3502 laminate and in Table 4.8 for the AS4/2220-1 laminate. Residual strength data for these impacted spepcimens are listed in Tables 4.4 and 4.5. Plots of impact energy versus damage area are shown in Figures 4-15 and 4-16 for the two laminates. A plot of impact damge area versus compressive failure strain is shown in Figure 4-17. T300/5208 data from other programs is included for comparison. Both AS4/32502 and AS4/2220-1 have significantly higher failure strains at a given damage area than T300/5208 (approx. 1000 μin./in.).

The AS4/3502 compression test data are reported in Table 4.4. Average failure strain and modulus of the unnotched room temperature dry coupons are much lower than expected. All unnotched coupons failed in combined bending and shear at either the top or bottom grip. It is suspected that the problem was due to a small amount of eccentricity in the loading fixture. Average failure strain of the open hole test coupons is as anticipated. Average modulus of the open hole coupons is lower than expected. Average failure strain of the 20 ft.-lb. and 30 ft.-lb. impacted coupons are as anticipated. The average modulus of the 20 ft.-lb impacted coupons is less than expected.

The AS4/2220-1 compression test data are reported in Table 4.5. Average failure strain of the unnotched room temperature dry coupons is much lower than expected. All unnotched coupons failed in combined bending and shear at either the top or bottom grip due to the loading fixture problem reported above. The average modulus of the AS4/2220-1 unnotched room temperature dry coupons is higher than that of the unnotched AS4/3502 coupons tested under the same conditions. Average failure strain of open hole coupons is much less than expected. The open hole average strain to failure was anticipated

TABLE 4.6. TRIAL IMPACT TEST RESULTS

AS4/3502 47 Plies $(\pm 45\ 90_2(\pm 45\ 0_2)_5)_S$ t_{avg} = 0.255 Resin Content = 33.3%						
		C-Scan Indications			Visual Indications	
Location ID	Energy (ft-lbs)	Width (in.)	Length (in.)	Area ($in.^2$)	Front	Back
14 - 1A	5	0	0	0	None	None
14 - 1B	50	1.80	3.00	3.35	Penetrated	8" Delam.
14 - 1C	10	1.25	1.41	1.30	Slight dent	0.3" Delam.
14 - 1D	40	1.44	1.80	2.05	Penetrated	7" Delam.
14 - 2A	15	1.40	1.50	1.70	Slight dent	0.5" Delam.
14 - 2B	40	2.04	2.26	3.45	Penetrated	6" Delam.
14 - 2C	20	2.00	2.25	2.95	Medium dent	1.5" Delam.
14 - 2D	30	1.45	1.94	2.05	Large dent	3.5" Delam.
14 - 3A	50	1.52	1.72	2.15	Penetrated	6" Delam.
14 - 3B	10	1.36	1.52	1.60	Slight dent	0.5" Delam.
14 - 3C	20	1.60	2.18	2.40	Medium dent	2.5" Delam.
14 - 3D	5	0	0	0	None	None
14 - 4A	10	1.35	1.40	1.40	None	None
14 - 4B	30	1.72	2.60	2.80	Large dent	3.5" Delam.
14 - 4C	15	1.40	1.63	1.60	Slight dent	1.5" Delam.
14 - 4D	20	1.92	2.30	2.70	Medium dent	2" Delam.

TABLE 4.7. IMPACT TEST RESULTS - AS4/3502

$(\pm 45\ 90_2(\pm 45\ 0_2)_5)_S$

Panel 15 48 Plies $t_{avg} = 0.262$ Resin Content = 35.1%

Panel 22 48 Plies $t_{avg} = 0.270$ Resin Content = NA

Location ID	Energy (ft-lbs)	C-Scan Indications			Visual Indications	
		Width (in.)	Length (in.)	Area ($in.^2$)	Front	Back
15 - 1A	22	1.90	2.00	2.30	Slight dent	1.0" Delam.
15 - 2A	20	1.80	1.84	2.35	Medium dent	1.0" Delam.
15 - 2B	30	1.94	1.88	3.15	Large dent	4.0" Delam.
15 - 3A	30	2.40	3.10	4.90	Medium dent	1.0" Delam.
15 - 3B	30	2.22	2.24	4.20	Large dent	4.0" Delam.
15 - 4A	20	1.72	2.20	2.85	Slight dent	1.0" Delam.
22 - 1A	22	2.00	1.90	3.20	Medium dent	2.5" Delam.
22 - 1B	22	1.80	2.16	2.85	Medium dent	3.0" Delam.

TABLE 4.8. IMPACT TEST RESULTS - AS4/2220-1

$(\pm 45\ 90_2(\pm 45\ 0_2)_5)_S$

Panel 35 48 Plies t_{avg} = 0.274 Resin Content = 35.0%

Panel 36 48 Plies t_{avg} = 0.270 Resin Content = 35.7%

Location ID	Energy (ft-lbs)	C-Scan Indications			Visual Indications	
		Width (in.)	Length (in.)	Area ($in.^2$)	Front	Back
35 - 2A	20	1.60	2.00	2.45	Slight dent	Dimple
35 - 2B	20	1.48	1.62	1.75	Slight dent	None
35 - 3A	20	1.80	2.04	2.55	Slight dent	Dimple
35 - 3B	30	2.42	2.90	5.00	Slight dent	1.0" Delam.
35 - 4A	30	2.30	3.32	5.30	Medium dent	1.0" Delam.
35 - 4B	30	2.04	2.64	3.70	Medium dent	1.0" Delam.
36 - 1A	20	1.70	1.90	2.30	Slight dent	0.25" Delam.
36 - 1B	20	1.64	1.74	1.95	Slight dent	Slight dimple
36 - 2B	20	1.76	1.90	2.30	Slight dent	0.75" Delam.

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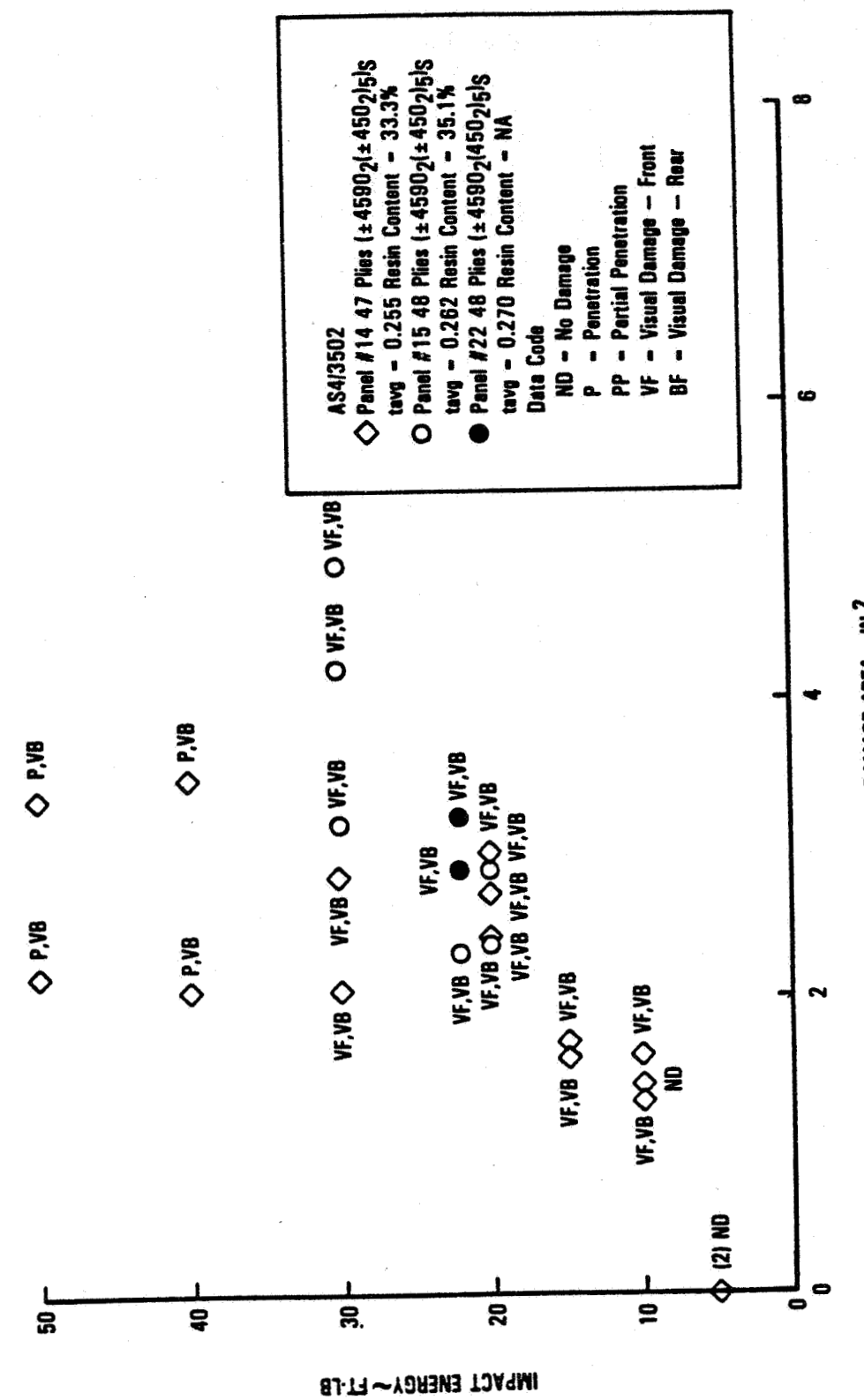


Figure 4-15: Impact behavior of AS4/3502.

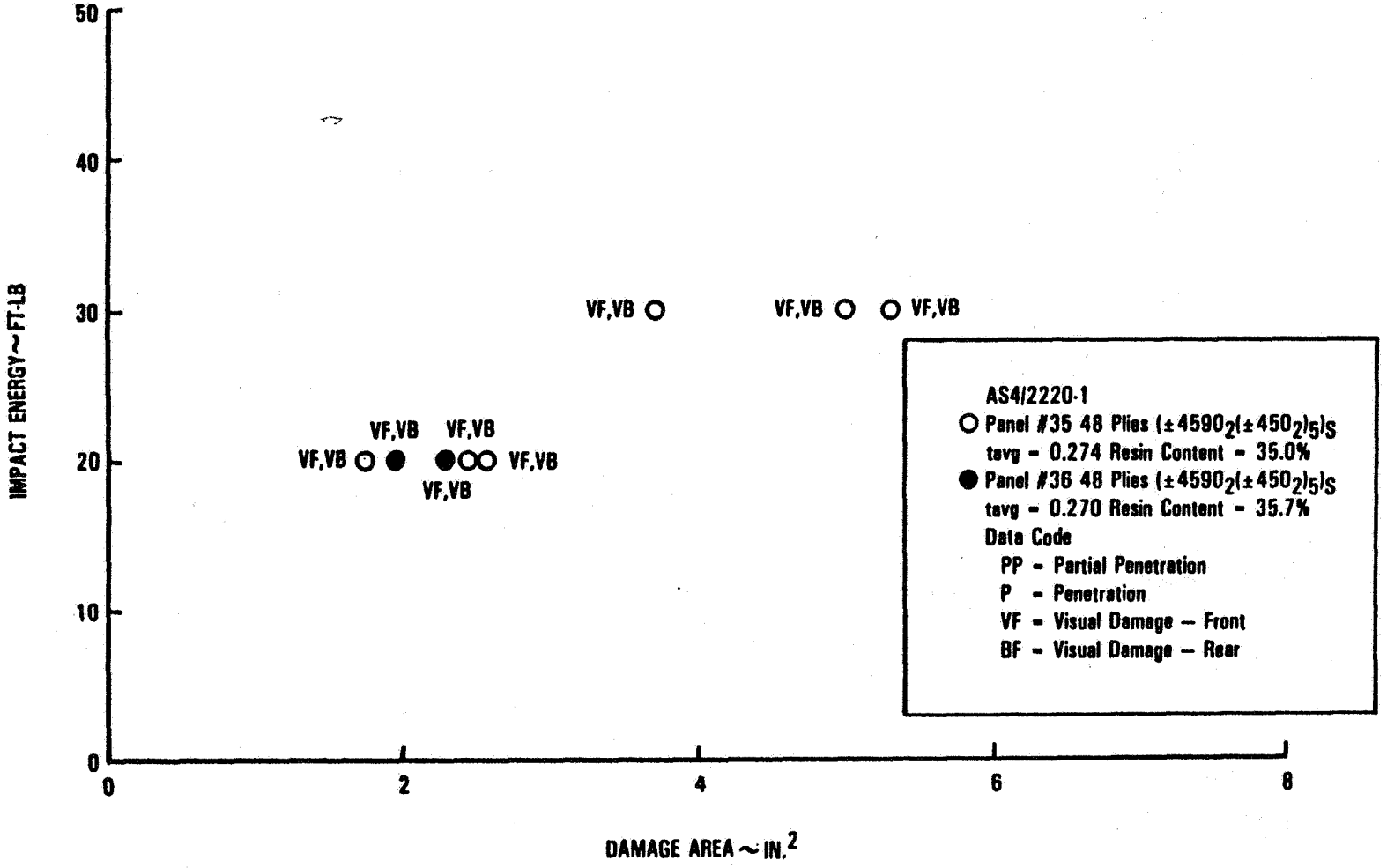


Figure 4-16: Impact behavior of AS4/2220-1.

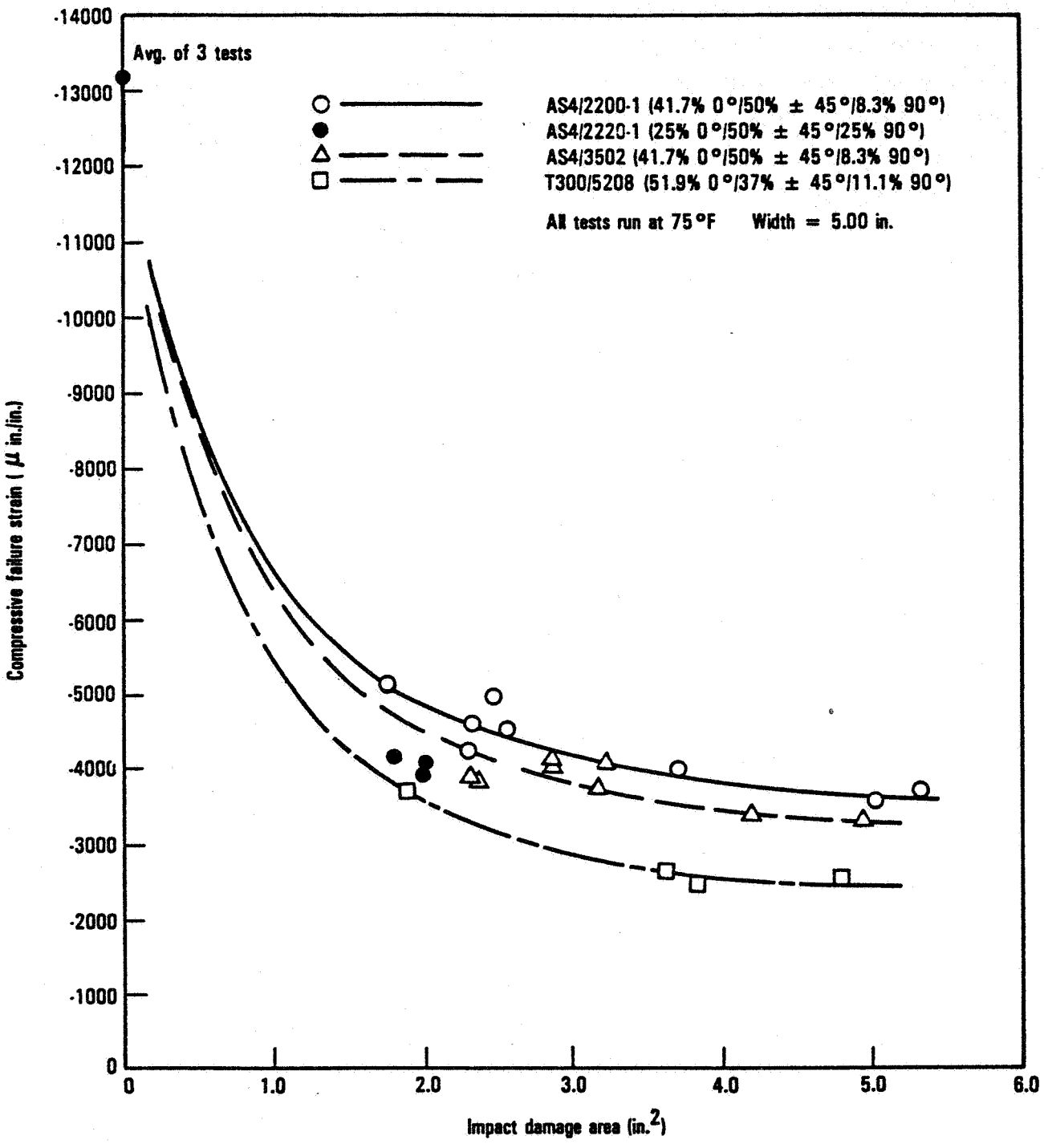


Figure 4-17: Effect of impact damage area on compressive failure strain.

to be as much as 1000 μin./in. higher based on data reported in Section 2.3 from tests run on quasi-isotropic laminates of the same material and thickness under the same conditions. The impacted AS4/2220-1 coupons have more damage area than the impacted AS4/3502 coupons for the same impact energy level. The average failure strains for the AS4/2220-1 coupons impacted with 20 ft.-lb. and 30 ft.-lb. are greater than those of the AS4/3502 coupons impacted at the same levels. The reduction in strength going from 20 ft.-lb. to 30 ft.-lb. is much greater for AS4/2220-1 than for AS4/3502. Average moduli of the impacted coupons are as anticipated. All impact damaged coupons failed through the impacted area.

Typical failures of notched, impacted, and undamaged 5 x 12 inch specimens are shown in Figure 4-18.

Specimens tested at 180°F wet were conditioned by soaking in water at 160°F for 45 days. Prior to soaking strain gages and tabs were applied. After soaking lead wires were attached. In most cases, however, the gages could not be balanced and had to be reinstalled.

Since failure strains and modulus were much lower than expected on the unnotched, undamaged 5 x 12 specimens a different restraint fixture was evaluated and found to produce values expected. Typically on AS4/3502 average failure strain with the "standard" fixture was 8325 μin./in., with the new fixture this value increased to 14040 μin./in. The new fixture uses a 2 inch wide by 9.625 inch long specimen. It is shown from three angles in Figure 4-19 mounted ready for test. The edge supports are a V-groove as shown in Figure 4-20. They are adjustable in width and attached to a back support plate which is free floating from any outside support. Fit of the V-groove bars to the specimeen is accomplished by installing a shim as indicated in Figure 4-20 of a thickness calculated to permit unrestrained Poisson expansion. After tightening the bolts the shims are removed before testing. Ends of the specimen are clamped with a flat loading bar and provide for 1/4 inch edge restraint. The bottom clamp bar rests on a

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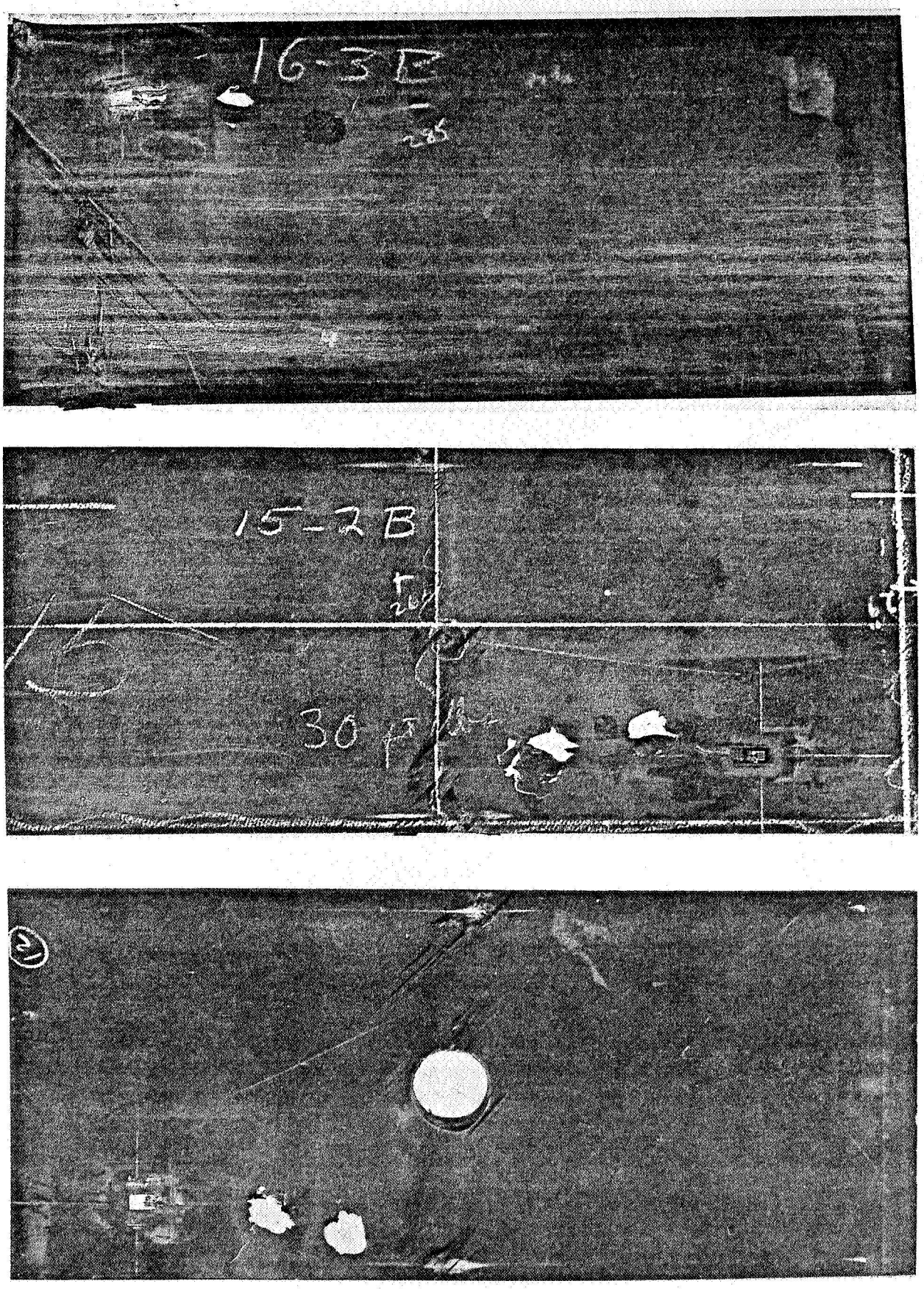


Figure 4-18: Typical Compression Failures of Notched, Impacted, and Undamaged 5 X 2 Inch 48-Ply Panels.

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Figure 4-19: V-Groove Compression Fixture Installed For Test In Front, Side and Back Views.

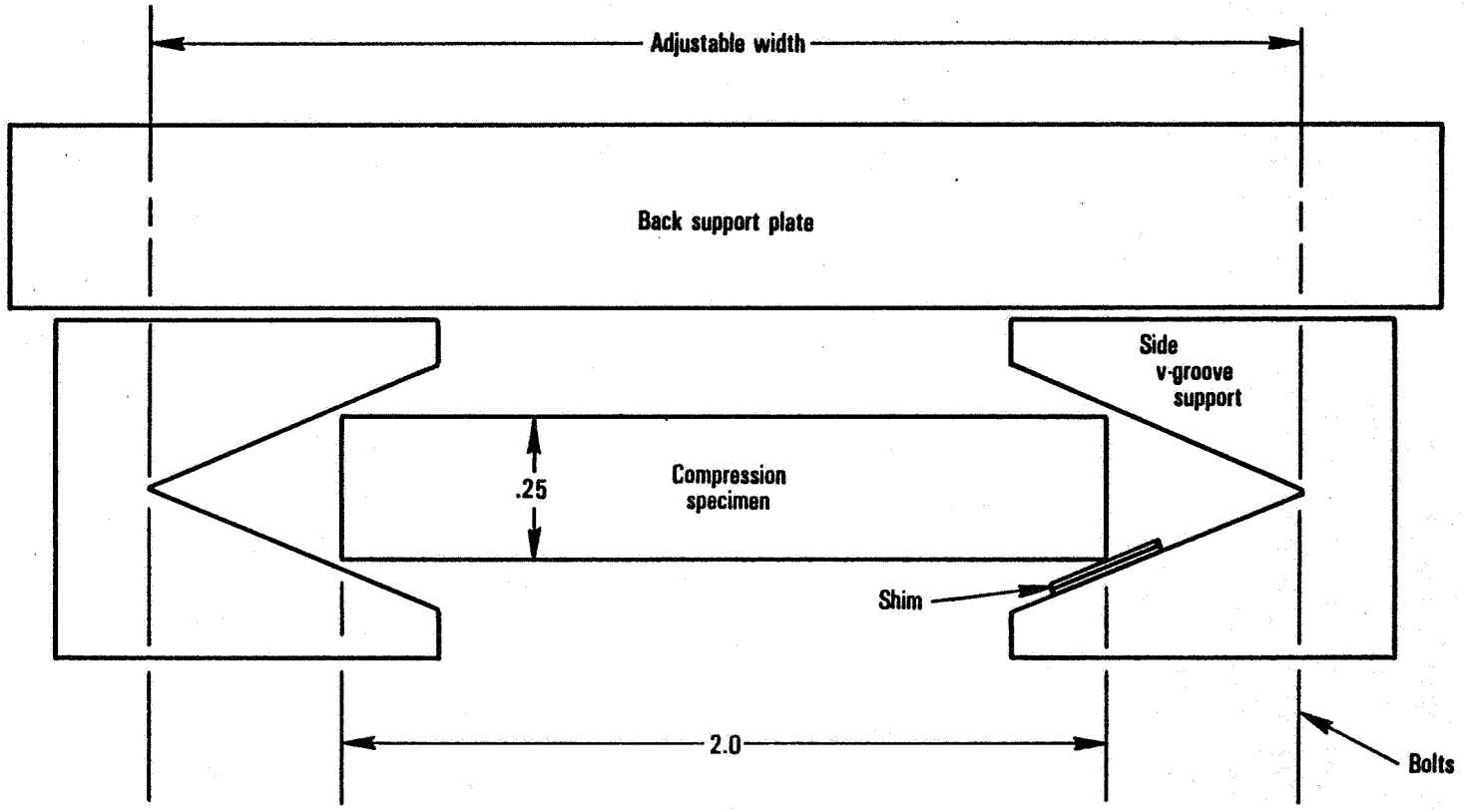


Figure 4-20: Plan View of V-groove Compression Support Fixture

spherical seat bearing. The test operator adjusts the spherical seat in both the X and Y axis until less than 0.001 inch maximum clearance is obtained between the top clamp bar and a loading bar attached to the load cell. Folded paper shims are used to support the back plate to a central vertical position on the specimen and left until 30 percent of the expected failure load is reached, then removed. Typical failures are shown in Figures 4-21 and 4-22 for 0° specimens and for 90° specimens in Figure 4-23. Failure modes are compressive and not the end type experienced with the standard fixture. Failure strains are also much higher, as seen in Tables 4.4 and 4.5, and are as expected.

The failure strain of the AS4/3502 material is higher than that of the AS4/2220-1 material. This is the reverse of the tension test results.

Four additional 2 inch wide specimens (2 each of AS4/2220 and 2 each of Celion/982) were run with this procedure and are reported in Section 2.3.

A problem with this fixture is that it is limited to 2 inch wide specimens which are inadequate for impact or notched specimens. A new fixture for larger specimens incorporating these features is being fabricated.

4.3 $\pm 45^{\circ}$ TENSILE TESTS

Tensile tests were performed on 12-ply laminates of AS4/3502 and AS4/2220-1 with a layup orientation of $\pm 45^{\circ}$. Test specimen geometry is shown in Figure 4-23 without the bonded fiberglass tabs. Lexan was used as tab material and gripping in MTS hydraulic grips. A T-gage was mounted in the test section for transverse and longitudinal strain monitoring.

Typical specimen failures are shown in Figure 4-25. Results are summarized in Tables 4.9 and 4-10. Specimen dimensional data, stress-strain curves

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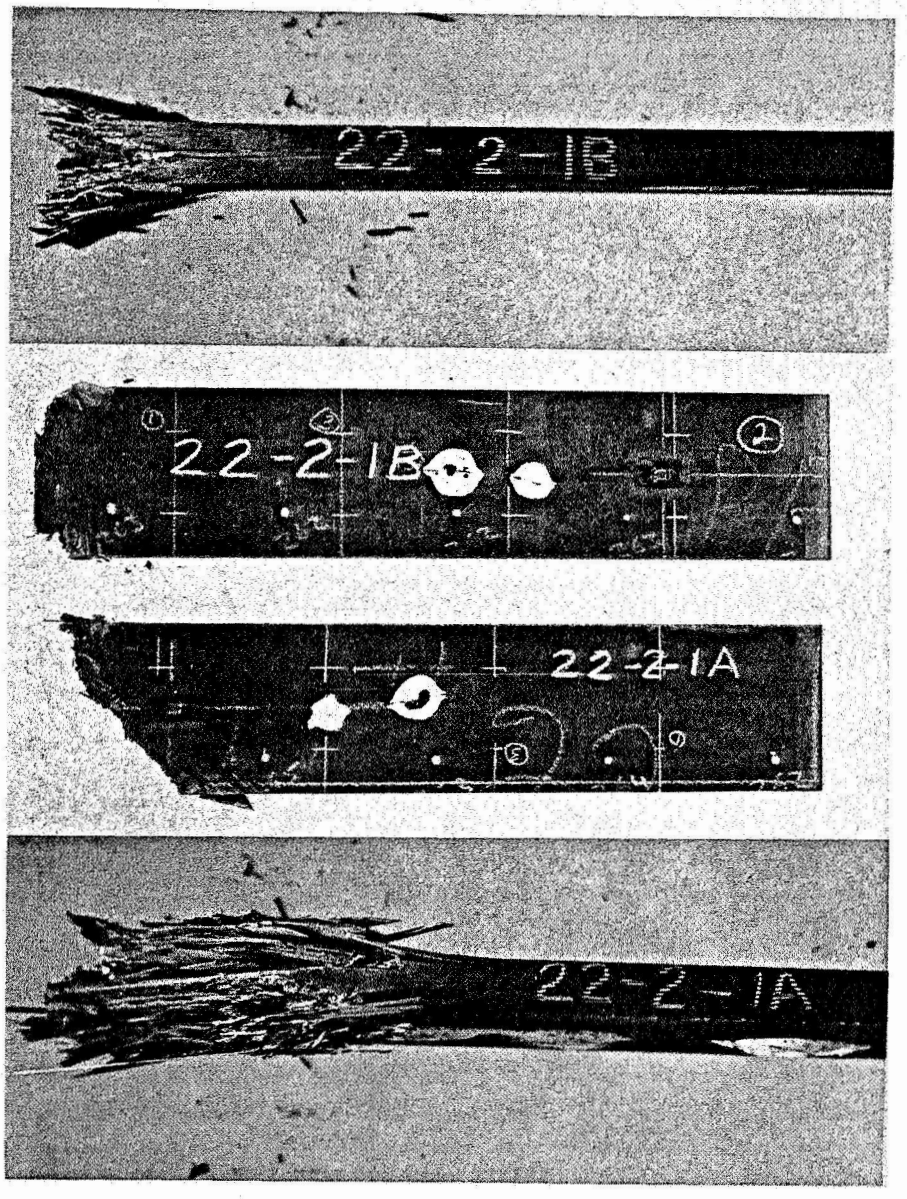


Figure 4-21: Typical Compression Failures of 2 Inch Wide 0^{o} Specimens on AS4/3502 Using the V-Groove Compression Fixture.

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Figure 4-22: Typical Compression Failures of 2-Inch Wide 0^{o} Specimens of AS4/2220-1 Using the V-Groove Compression Fixture.

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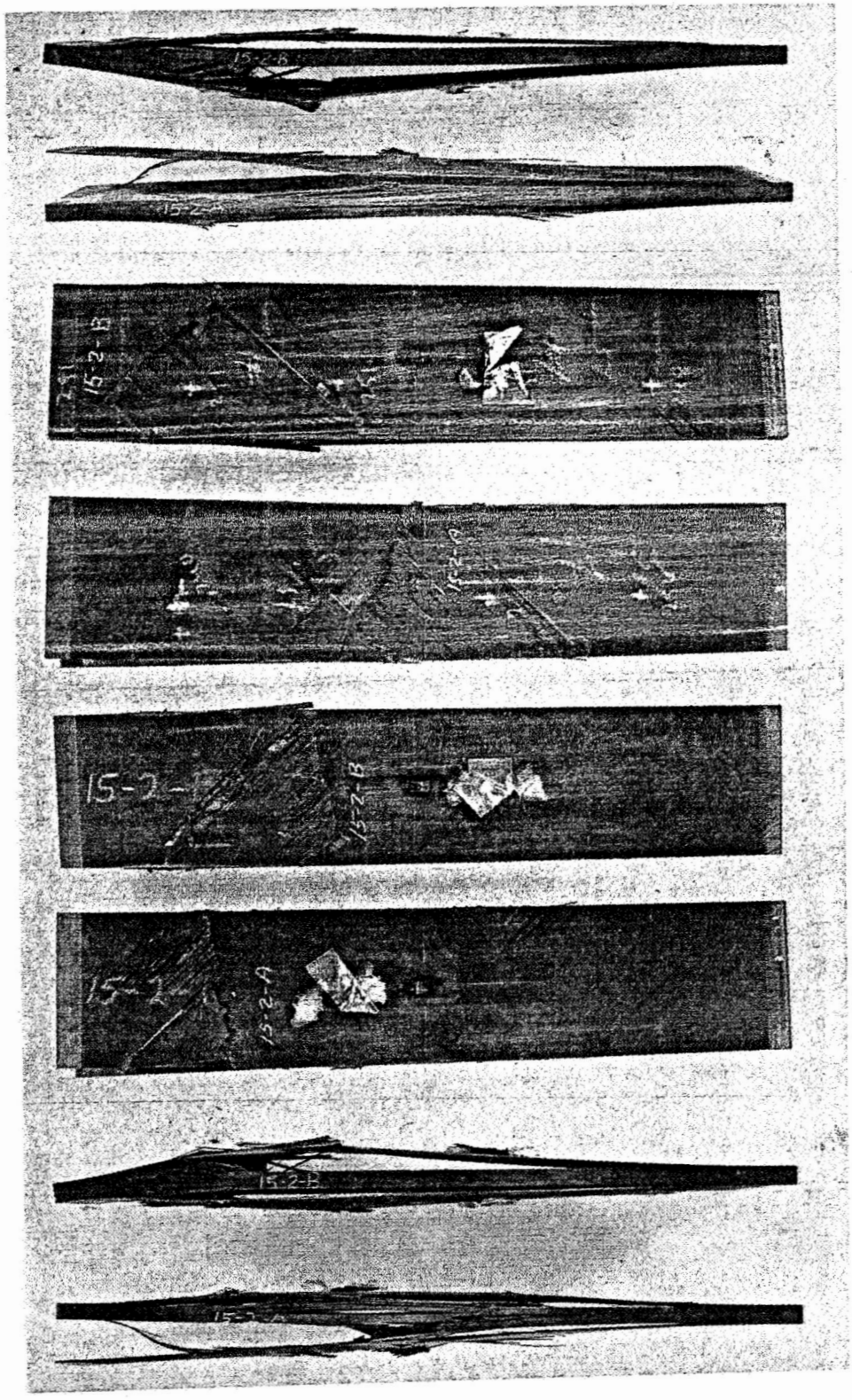


Figure 4-23: Typical Compression Failures of 2-Inch Wide 90^{o} Specimens of AS4/3502 Using The V-Groove Compression Fixture.

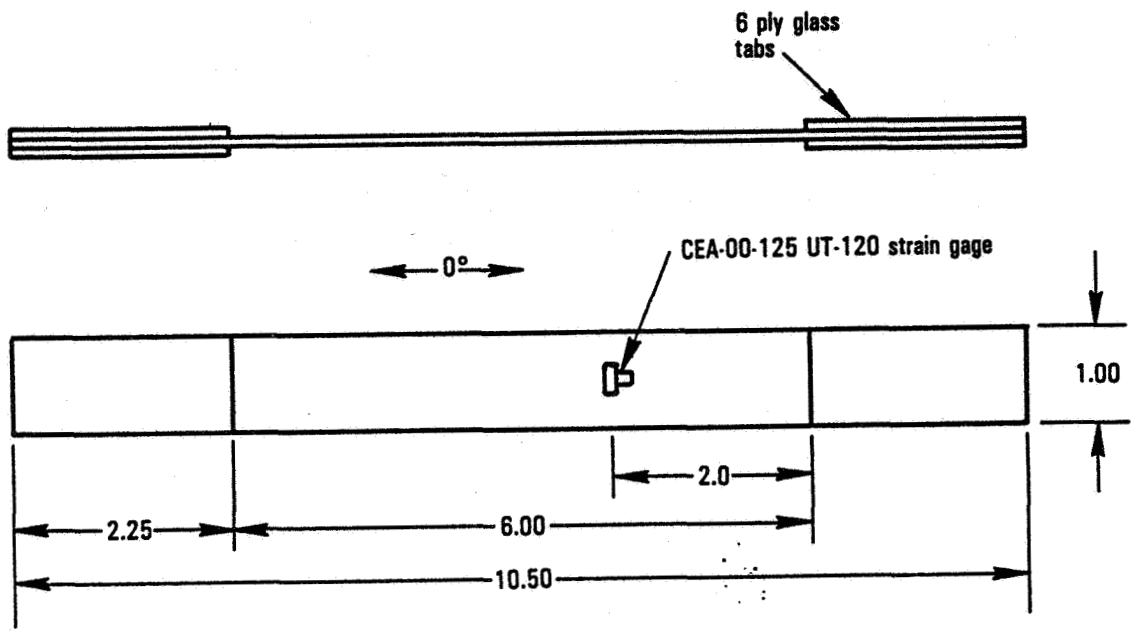


Figure 4-24: $\pm 45^{\circ}$ and 0° Tensile Test Specimen Geometry

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Figure 4-25: $\pm 45^{\circ}$ Tensile Specimen Failures. Top Specimen is AS4/3502 and the Bottom is AS4/2220-1.

TABLE 4.9 - AS4/3502 ±45° TENSION TEST DATA

Laminate Orientation: $(\pm 45°)_6$
Laminate Resin Content: 31.5%
Test Condition: 75°F Dry

Coupon Id.	Thickness (in.)	Width (in.)	Failure Load (lb)	Tensile Failure Stress (ksi)	Tensile Modulus (msi)	Shear Failure Stress (ksi)	Shear Modulus (msi)	Poisson's Ratio
17-1	0.062	1.002	1562	25.36	2.64	12.68	0.78	0.7167
17-2	0.062	1.002	1537	24.63	2.76	12.32	0.79	0.7143
17-3	0.063	1.002	1549	24.74	2.55	12.37	0.74	0.7500
17-4	0.062	1.002	1538	24.73	2.53	12.37	0.74	0.6875
17-5	0.062	1.000	1525	24.60	2.77	12.30	0.79	0.7241
AVERAGE				24.81	2.65	12.41	0.77	0.7185

TABLE 4.10 - AS4/2220-1 ±45° TENSION TEST DATA

Laminate Orientation: $(\pm 45°)_6$
Laminate Resin Content: 29.8%
Test Condition: 75°F Dry

Coupon Id.	Thickness (in.)	Width (in.)	Failure Load (lb)	Tensile Failure Stress (ksi)	Tensile Modulus (msi)	Shear Failure Stress (ksi)	Shear Modulus (msi)	Poisson's Ratio
37-2	0.065	1.001	2033	31.23	①	15.62	①	①
37-3	0.065	1.001	2040	31.53	2.35	15.77	0.71	0.7273
37-4	0.065	1.001	1996	30.66	2.50	15.33	0.68	0.7059
37-5	0.065	1.001	2108	32.18	2.38	16.09	0.72	0.6667
AVERAGE				31.40	2.41	15.70	0.70	0.7000

① Data not available.

and shear stress-shear strain curves are contained in Appendix B-4. Shear failure stresses were 12.41 ksi for the AS4/3502 laminate and 15.70 ksi for the AS4/2220-1 laminate.

Strain to failure data is not presented in all cases due to the very high strain levels (80,000 + μ in./in.) reached prior to failure. A trade-off in computer data taking rate versus the total data capacity led to terminating strain recording beyond 40,000 μ in./in. for the AS4/3502 and 20,000μ in./in. for the AS4/2220-1 in order to improve data resolution of the lower part of the stress-strain curve which contains the primary data of interest.

Failure strains ranged in the AS4/3502 laminate from 16,000 to 40,000+μ in./in. and in the AS4/2220-1 all specimens were over 20,000 μin./in. but since the data was truncated at 20,000 μin./in. no value of maximum strain was recorded. Loading rates were varied from 0.2 in/min on specimen 37-4 to 0.03 in/min on specimen 37-3. All others were loaded at 0.1 in./min.

4.4 0° TENSION TESTS

Tensile tests were performed on 12-ply 0° laminates of AS4/3502 and AS4/2220-1. Specimens were of the geometry shown in Figure 4-24 with one T type strain gage for recording axial and transverse strain to failure. Fiberglass tabs were bonded to the specimen grip ends. Tests were run in an MTS machine at a loading rate of 0.05 in/min with hydraulic grips. Test results are summarized in Tables 4.11 and 4.12. Failure strains averaged 11612 μin./in. in the AS4/3502 and 14176 μ in./in. in the AS4/2220-1. Both longitudinal and transverse stress-strain curves are contained in Appendix B-5 along with specimen measurement tabulations.

Failures in these specimens were catastrophic over most of the test section; locating an origin on most was difficult. Typical failures are shown in Figure 4-26. As seen in the end tabs the hydraulic grips contacted the fiberglass 0.15 inch from the inboard end and had progressively deeper

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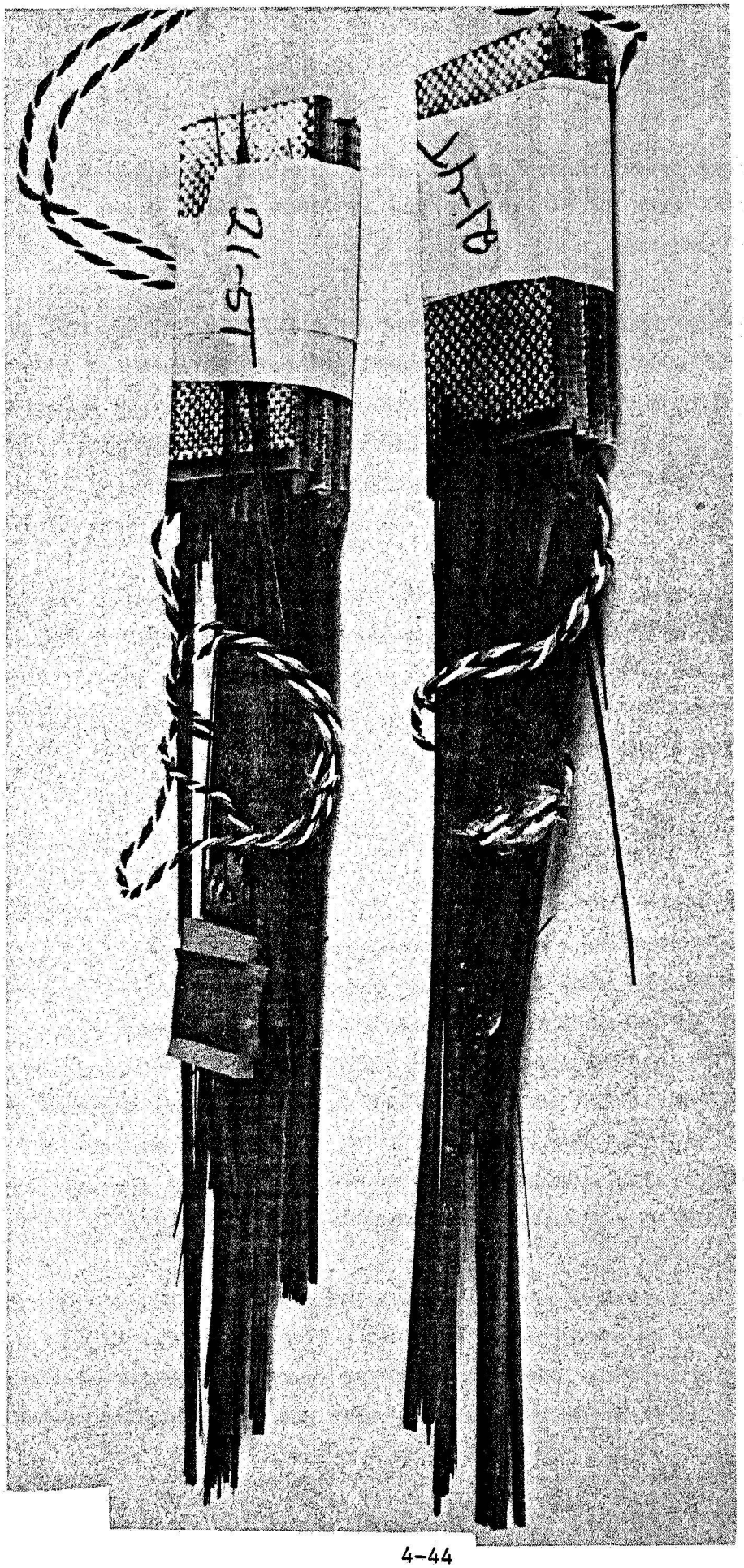


Figure 4-26: 0^{o} Tensile Specimen Failures

TABLE 4.11 - AS4/3502 0° TENSION TEST DATA

Laminate Orientation: 0°_{12}
Laminate Resin Content: 28.4%
Test Condition: 75°F Dry

Coupon Id.	Thickness (in.)	Width (in.)	Failure Load (kips)	Failure Stress (ksi)	Failure Strain (μin./in.)	Modulus (msi)	Poisson's Ratio
21-1T	0.056	0.991	11.82	213.33	9882	22.00	0.3089
21-2T	0.058	1.005	12.70	218.94	12700	21.20	0.2955
21-3T	0.060	1.008	14.31	236.54	11130	21.70	0.2987
21-4T	0.059	1.007	14.68	246.35	11590	21.15	0.3065
21-5T	0.059	1.009	14.95	250.75	12560	20.80	0.3108
21-6T	0.059	1.005	14.76	250.32	11810	21.65	0.2970
AVERAGE			13.87	236.04	11612	21.42	0.3029

TABLE 4.12 - AS4/2220-1 0° TENSION TEST DATA

Laminate Orientation: 0°_{12}
Laminate Resin Content: 30.8%
Test Condition: 75°F Dry

Coupon Id.	Thickness (in.)	Width (in.)	Failure Load (kips)	Failure Stress (ksi)	Failure Strain (μin./in.)	Modulus (msi)	Poisson's Ratio
38-1T	0.058	1.009	17.65	299.53	14010	20.45	0.3024
38-2T	0.058	1.009	17.11	290.95	14000	19.80	0.3190
38-3T	0.058	1.009	18.10	307.69	14510	20.10	0.3130
38-4T	0.058	1.009	17.58	300.89	14200	21.10	0.3000
38-5T	0.056	1.007	17.11	303.86	14010	20.75	0.3141
38-6T	0.057	1.008	16.99	293.59	14330	20.25	0.3127
AVERAGE			17.42	299.42	14176	20.24	0.3102

indentations in the tab toward the outboard end. This procedure was used to avoid a sharp stress concentration at the tab inboard edge. However, on specimen 21-1T the hydraulic grip came out to the inboard edge of the tab and apparently contributed to a failure at that point. Since that specimen also has an abnormally low failure stress (Table 4.11) it is probably not a valid test point. Specimen 21-2T is similarly low but visual examination of the specimen indicates no abnormality. The failure is well away from the tabs. Specimen 21-3T failed at the tab edge, the same as 21-1T, but the grip was 0.15 inch away from the tab edge, and its strength value is high.

4.5 90° TENSION TESTS

Five specimen each of unidirectional 12-ply AS4/3502 and AS4/2220-1 were fabricated into sandwich beam specimens shown dimensionally in Figure 4-27. The graphite/epoxy laminates were bonded to an aluminum honeycomb core with an opposite face sheet of 12-ply fiberglass per Drawing TL1031-5. Cross sectional dimensions of the beams are listed in Table 4.13. A single axial strain gage was mounted on the specimen centerline.

Specimens were loaded in a four point bending fixture, as shown in Figure 4-28, with the graphite/epoxy laminate on the lower tension surface of the beam. Load-strain plots were taken to failure on each specimen, and are contained in Appendix B-6. Test data are summarized in Tables 4.14 and 4.15. While failure stresses are essentially the same for both laminates, failure strain is significantly higher (7260 vs 6577 μ in./in.) in the AS4/2220-1 than in the AS4/3502. Loading rate for all specimens was 0.05 in/minute. Failures occurred randomly within $\pm$2.5 in. of the centerline in the graphite/epoxy face sheet. No breaks in the fiberglass or crushing of the honeycomb core were noted.

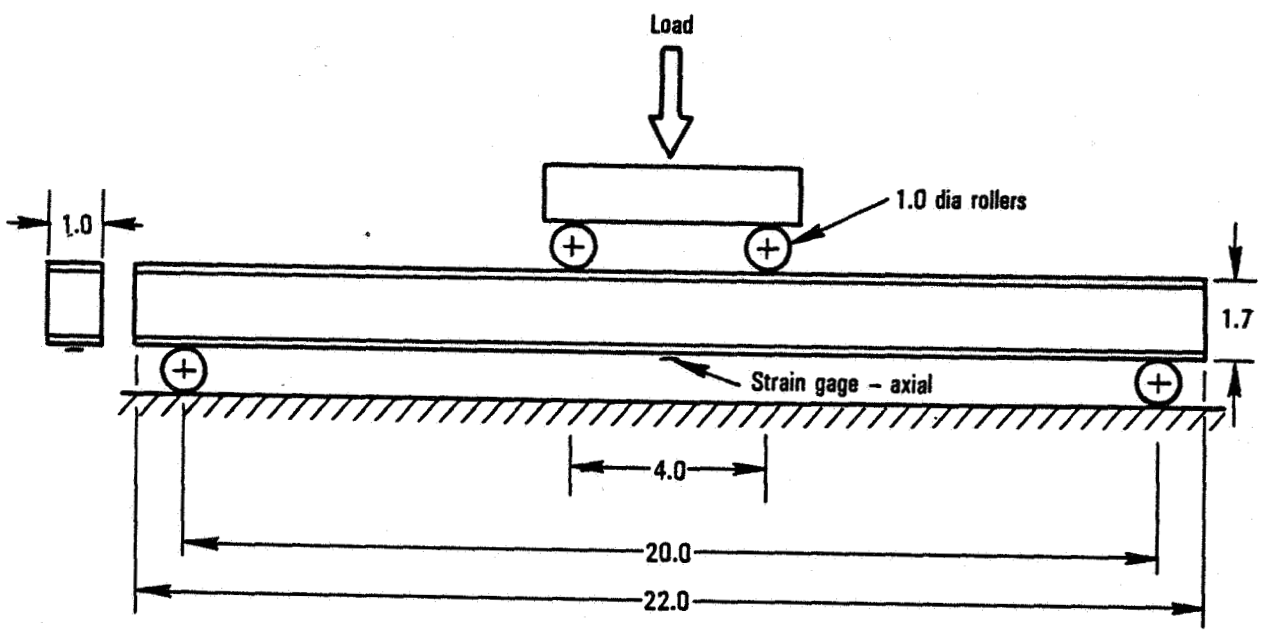


Figure 4-27: 90° Tension Test Setup Geometry. All Dimensions in Inches

TABLE 4.13 SANDWICH BEAM GEOMETRY

Specimen ID	$T_{G/E}$ (in.)	T_{FG} (in.)	T_o (in.)
21-2	.060	.123	1.6895
21-3	.060	.121	1.6870
21-4	.058	.122	1 6900
21-5	.057	.122	1.6870
21-6	.055	.121	1.6885
38-1	.053	.122	1.6845
38-2	.054	.123	1.6865
38-3	.055	.122	1.6855
38-4	.056	.122	1.6860
38-5	.058	.122	1.6880

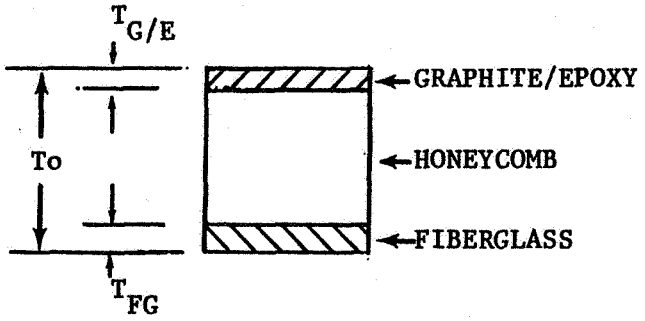


TABLE 4.14 - AS4/3502 90° TENSION TEST DATA

Laminate Orientation: $90°_{12}$
Laminate Resin Content: 28.4%
Test Condition: 75°F Dry

Coupon Id.	Thickness (in.)	Width (in.)	Failure Load (lb)	Failure Stress (ksi)	Failure Strain (μin./in.)	Modulus (msi)
21-2	0.060	0.9985	598	9.98	6227	1.61
21-3	0.060	1.005	569	9.44	6155	1.57
21-4	0.058	1.008	610	10.43	6402	1.66
21-5	0.057	1.0075	611	10.64	6401	1.70
21-6	0.055	1.0135	692	12.41	7698	1.67
AVERAGE			616	10.58	6577	1.64

TABLE 4.15 - AS4/2220-1 90° TENSION TEST DATA

Laminate Orientation: $90°_{12}$
Laminate Resin Content: 30.8%
Test Condition: 75°F Dry

Coupon Id.	Thickness (in.)	Width (in.)	Failure Load (lb)	Failure Stress (ksi)	Failure Strain (μin./in.)	Modulus (msi)
38-1	0.053	1.011	556	10.38	6721	1.55
38-2	0.054	1.010	563	10.32	7079	1.49
38-3	0.055	1.011	619	11.13	7816	1.48
38-4	0.056	1.010	611	10.80	7542	1.48
38-5	0.058	1.0125	591	10.06	7142	1.44
AVERAGE			588	10.54	7260	1.49

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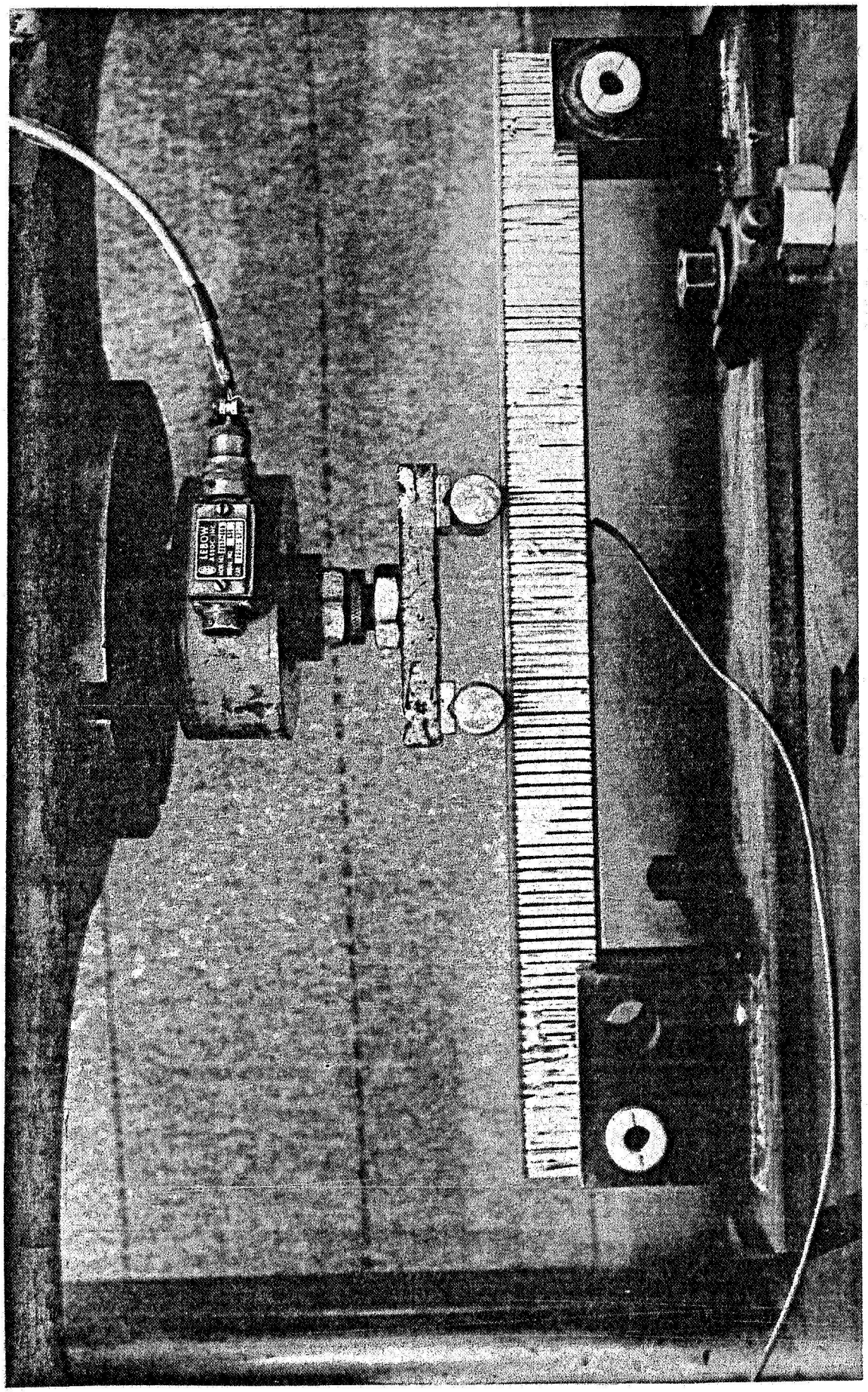


Figure 4-28: 90^{o} Tension Test Setup. Graphite/Epoxy Sheet is on the Bottom Surface of the Sandwich Beam.

4.6 DOUBLE CANTILEVERED BEAM (DCB) TESTS

Tests were conducted on five specimens each of 12-ply (0°) AS4/3502 and AS4/2220-1 bonded to aluminum beams as shown in Figure 4-29. This test was done in accordance with NASA Standard Test ST-5. During laminate layup a sheet of 0.002 inch thick teflon was partially inserted between plies 6 and 7 to act as a crack starter in the beam specimen.

The test objective was to obtain data on load versus crack arrest distance. This was accomplished by loading the specimen shown in Figure 4-30 in an axis perpendicular to the laminate so that a crack will run down the length of the laminate. Details of the test setup are shown in Figures 4-30 and 4-31, where the specimen is installed in a 12 kip static test machine with pin-ended clevises at the specimen and spherical seats on the outboard ends of the loading rods where they attach to the loading head. This arrangement was used to avoid application of bending loads due to any load column misalignment. A clip gage was attached to knife edges bonded to the ends of the specimen to measure crack opening displacement (COD). A traveling microscope attached to a dial gage reading to 0.001 inch was used to measure crack extension. Two microscopes were used during the tests, one on each side of the specimen, but for clarity one was removed from the photos in Figures 4-30 and 4-31. The COD gage was attached to an X-Y plotter along with load to produce load-COD curves so that crack growth could be readily observed. Load was applied at a constant rate until the crack started to grow from the teflon starter at which time loading was stopped and held at the displacement position where the crack began to grow. At that point the load dropped off rapidly at first then gradually decreased to almost a stop. The crack growth rate decayed similarily. However, in these tests neither the load drop-off nor the crack growth completely stopped even after waiting up to 30 minutes. From a practical test cost standpoint the average wait from initial cracking to reloading averaged about 12 minutes, the actual values for each reading are contained in Appendix B-7. The hold times vary

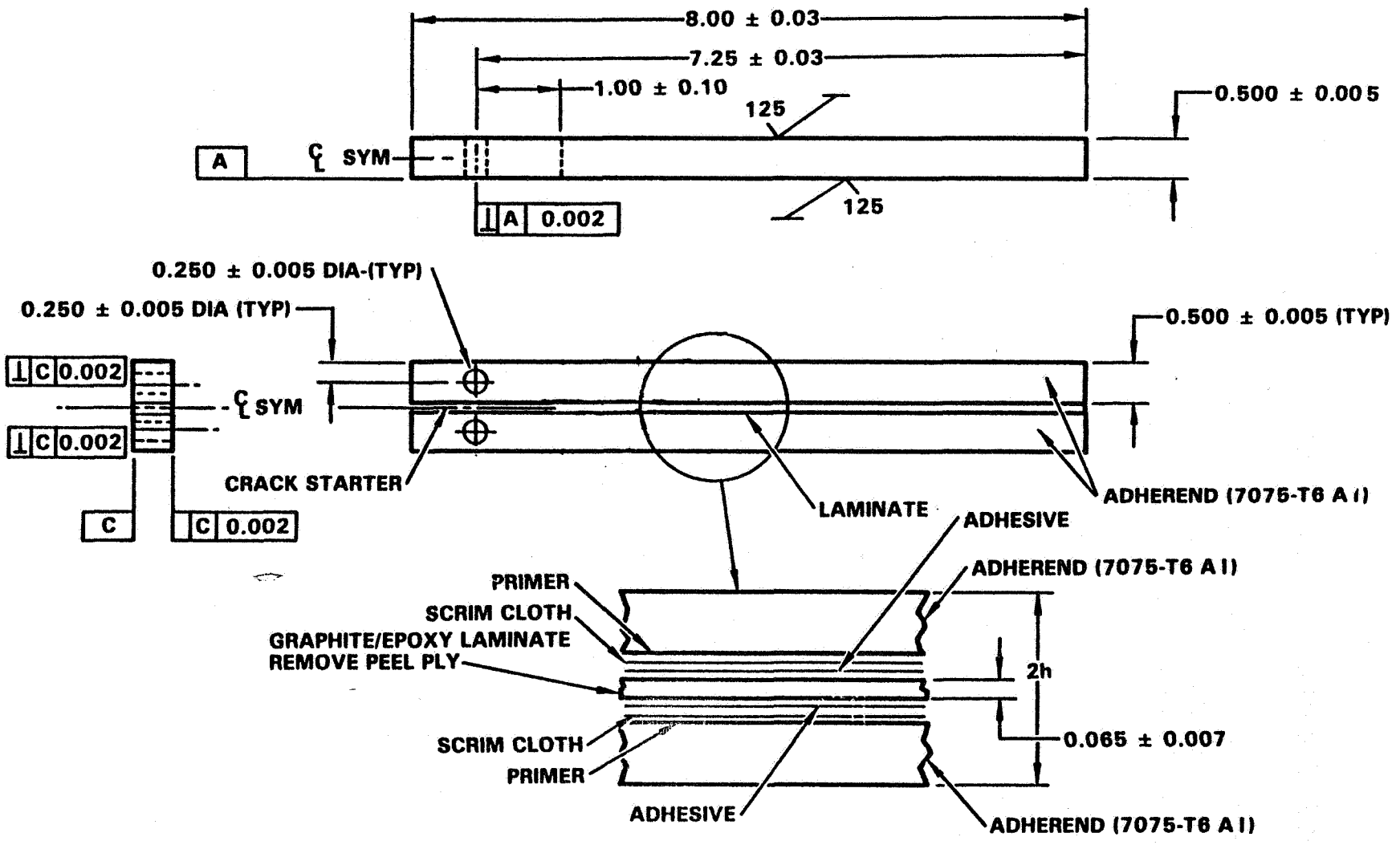


Figure 4-29: Double Cantilevered Beam (DCB) Test Specimen

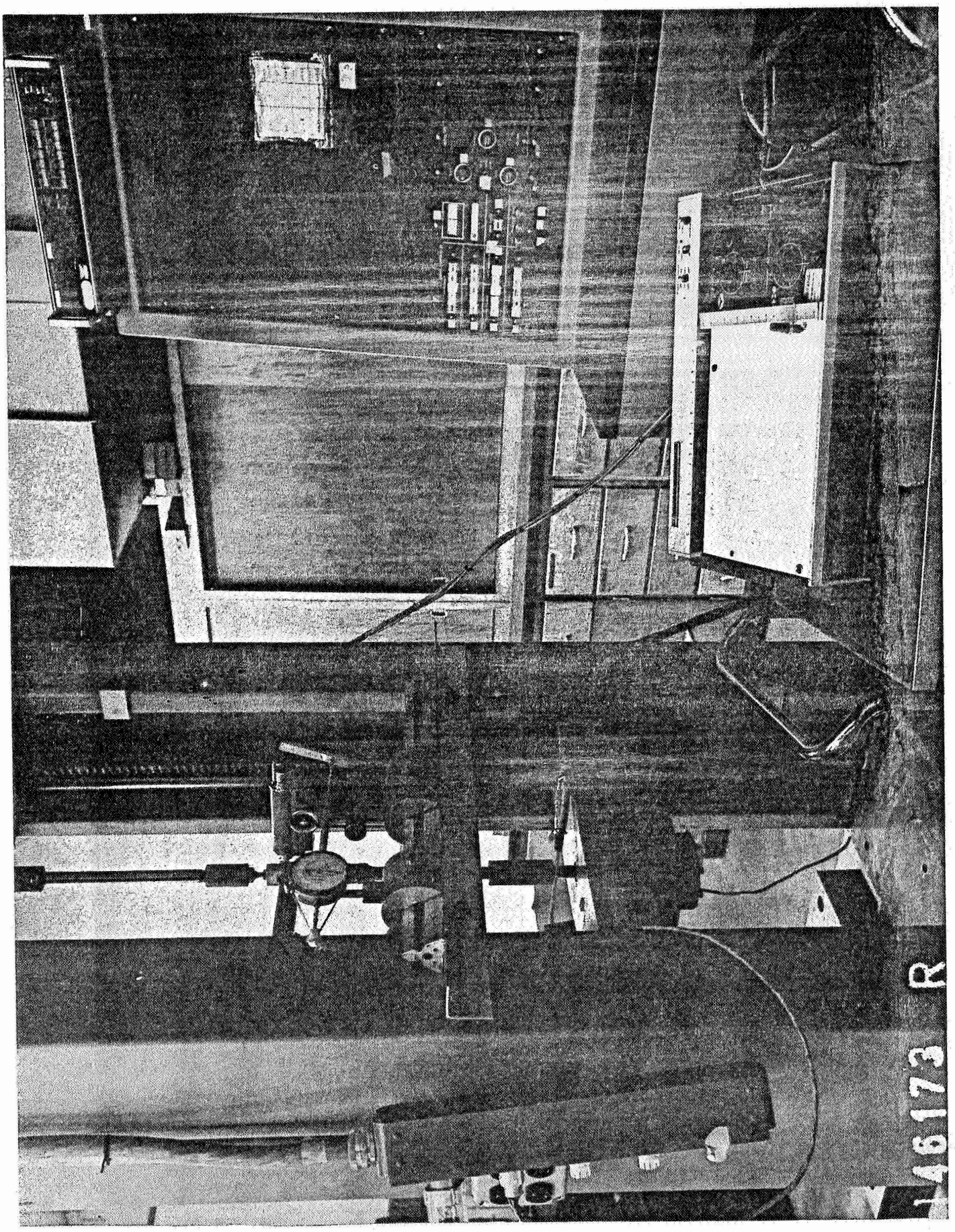


Figure 4-30: Overall View of DCB Test in 12 kip Static Test Machine.

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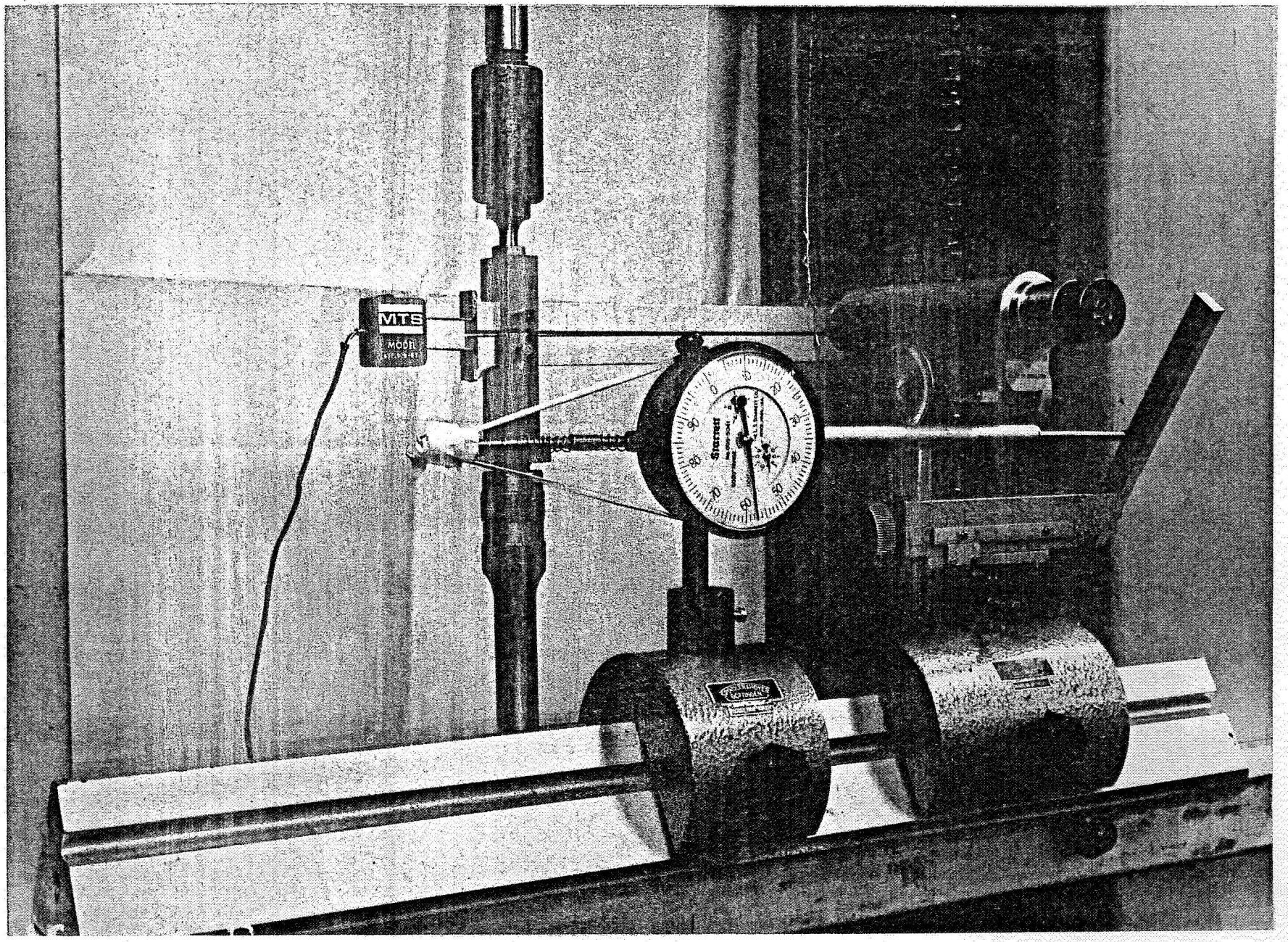


Figure 4-31: Detail View of Clip Gage Mounting Procedure and Traveling Microscope For Crack Length Measurement on DCB Specimens.

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depending on the observed rate of crack growth. The loading resumption point was as near crack arrest as practically feasible.

Once the crack basically arrested, loading was resumed until the crack started to grow again as observed by a drop in load on the load-COD plot. This procedure was repeated until the crack had grown to about three inches from the teflon starter. These load-COD plots are also contained in Appendix B-7 along with a tabulation of the front and rear crack length at each arrest point and the corresponding loads. Coupon dimensional data are summarized in Table 4.16.

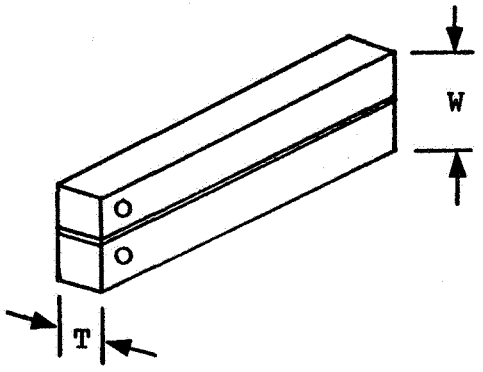
Test results were analyzed in accordance with ST-5 and are presented in Figures 4.32 and 4.33 as G_{IC} versus crack length for each specimen. As seen the data scatter, particularly in the AS4/2220-1 specimens, is quite high. Analysis of tested specimens reveal several anomalies which may have contributed to this scatter. Specimens fabricated from panel 21 had the teflon crack starter sheet misoriented as shown in Figure 4-34, which produced different crack lengths on either side of the specimens. This misalignment was also noted in Panel 38 but to a much lesser extent.

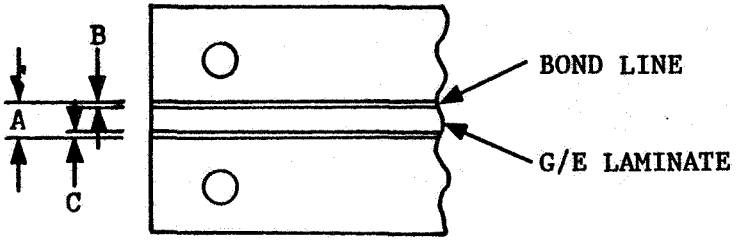
Observation of crack growth in several of the specimens revealed crack growth out of plane from the original crack between plies 6 an 7. Figure 4-35 of specimen 38-5 is a good example of shifting by one ply. Figure 4-36 of specimen 21-5 shows crack branching near the tip of the teflon starter flaw. These crack branchings generally are observed only on one side of the specimen, the other side usually appears normal. In one instance, Figure 4-37, the crack stopped propagating along the 6/7 ply interface and shifted out of the laminate to the adhesive between the aluminum beam and the laminate surface.

Other experimentors have suggested that part of our problem may be due to a slight excentricity caused by the wire support on the outboard end of the specimen as seen in Figure 4-31. In this test setup the upper half of the

TABLE 4.16: DCB COUPON DIMENSIONS

	Coupon ID	W (in.)	T (in.)	A (in.)	B (in.)	C (in.)
AS4/3502	21-2	1.067	.5035	.060	.004	.004
	21-3	1.068	.5040	.060	.003	.002
	21-4	1.069	.5010	.061	.002	.002
	21-5	1.069	.5014	.060	.002	.002
	21-6	1.070	.5031	.060	.003	.002
AS4/2220-1	38-1	1.062	.5043	.058	.003	.003
	38-2	1.063	.5031	.058	.003	.003
	38-3	1.064	.5035	.058	.004	.004
	38-4	1.064	.5025	.062	.004	.004
	38-5	1.065	.5046	.061	.004	.004





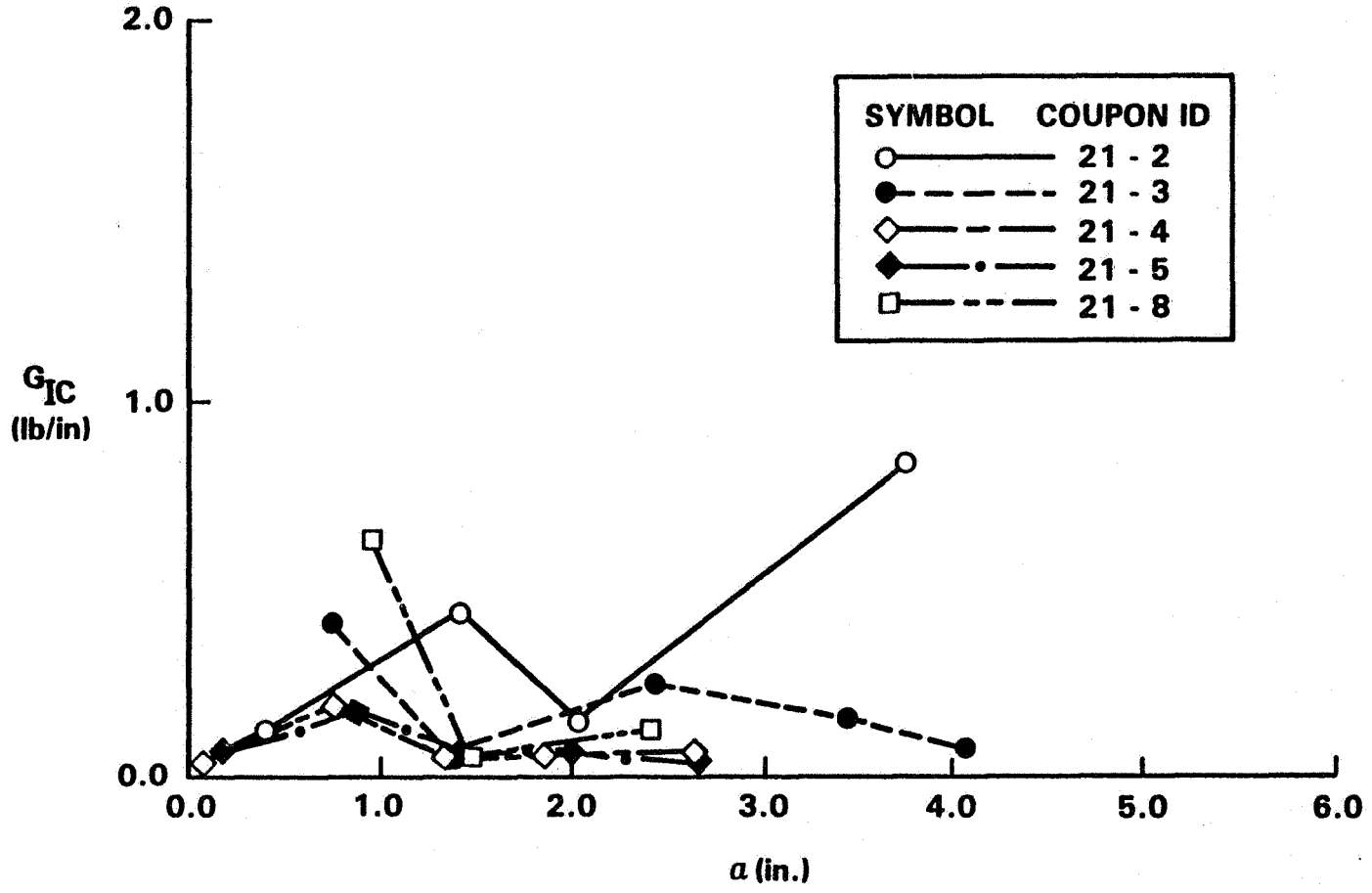


Figure 4-32: DCB Test Results - AS4/3502

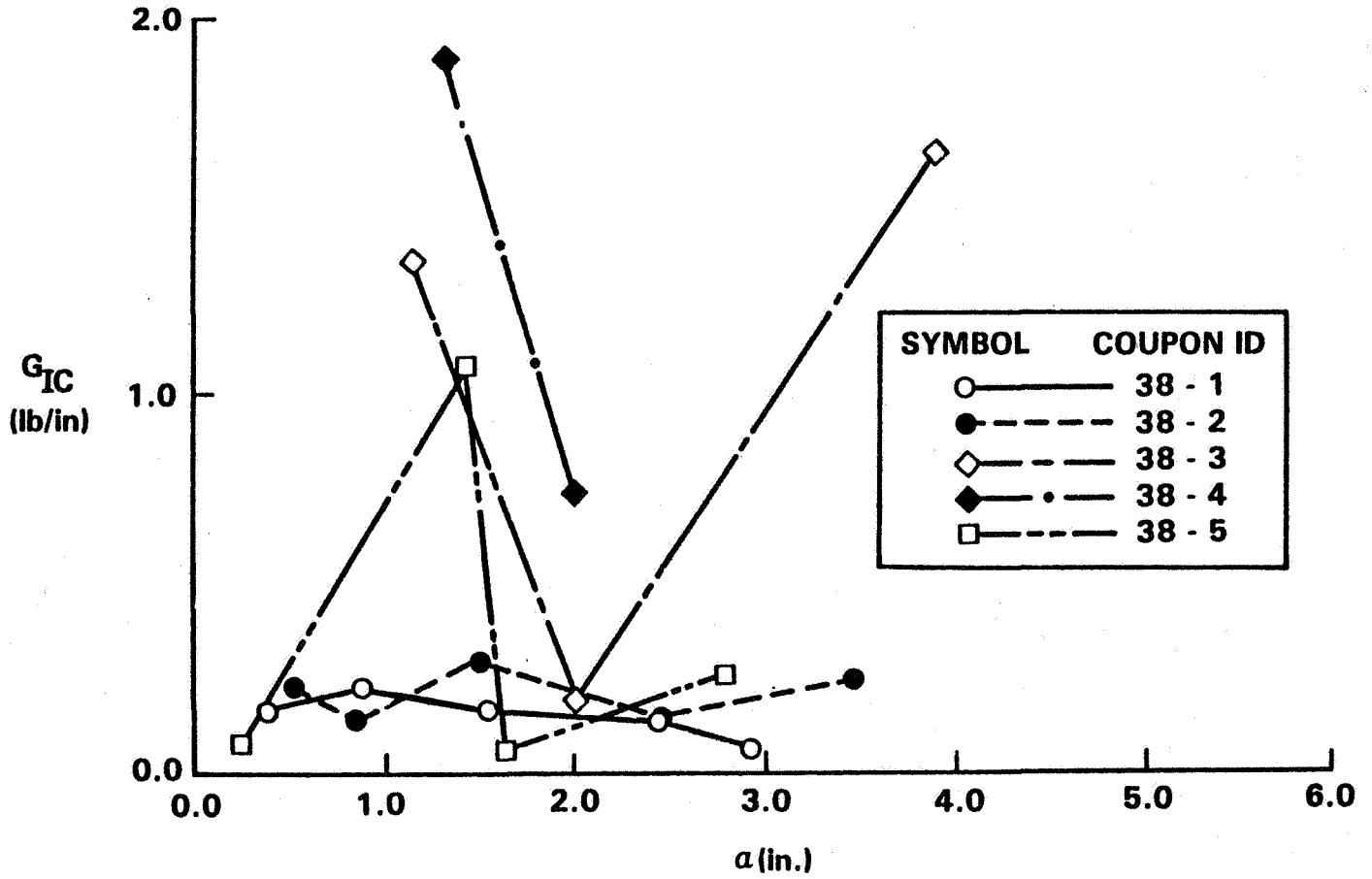


Figure 4-33: DCB Test Results - AS4/2220-1

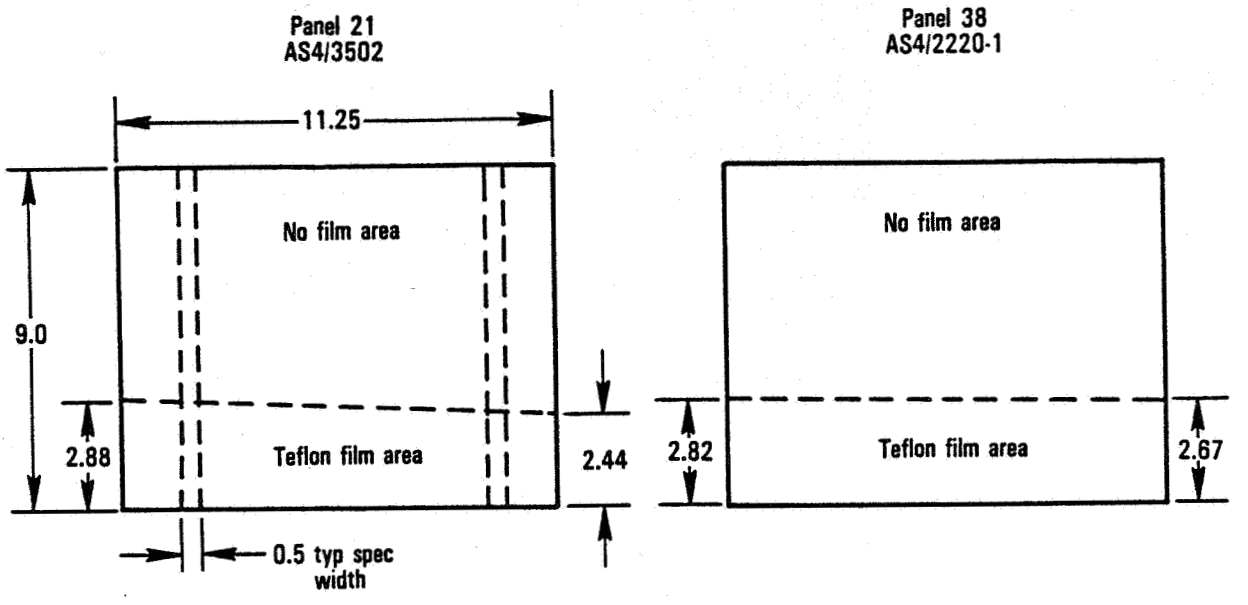
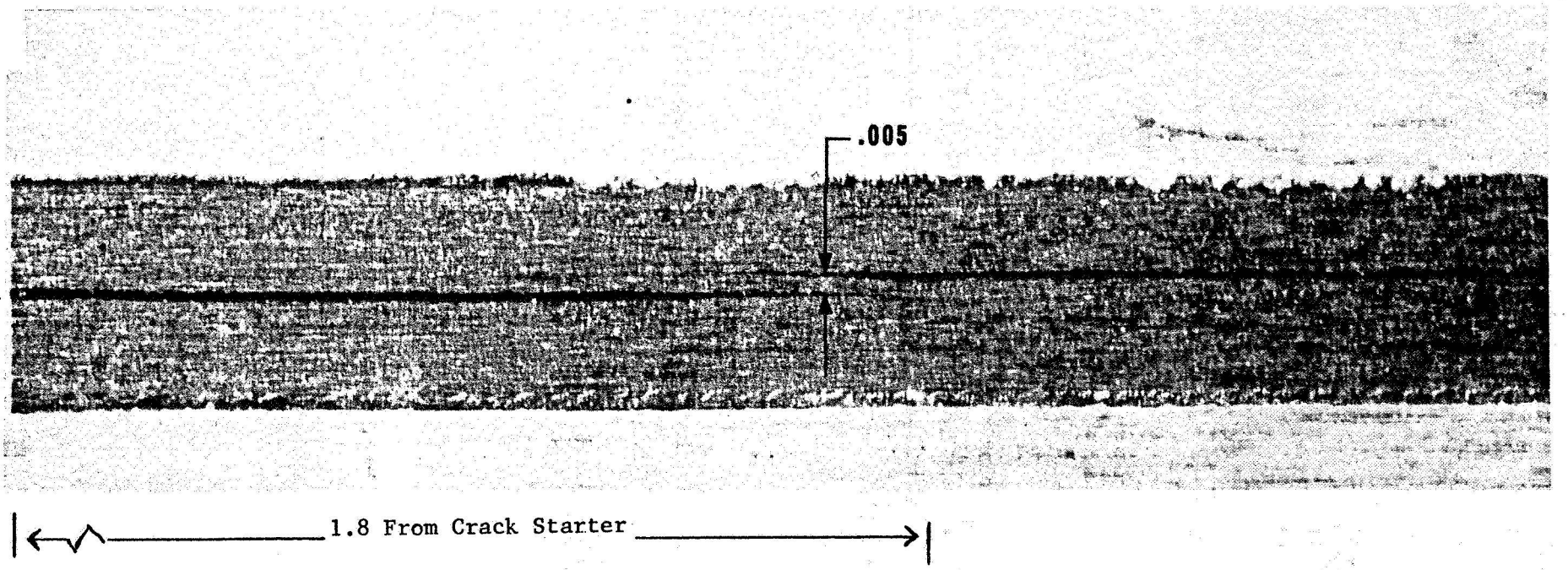


Figure 4-34: Teflon Film Misalignment in DCB Specimen Fabrication Panel



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Figure 4-35: Closeup of DCB Specimen 38-5 Showing Crack Branching.

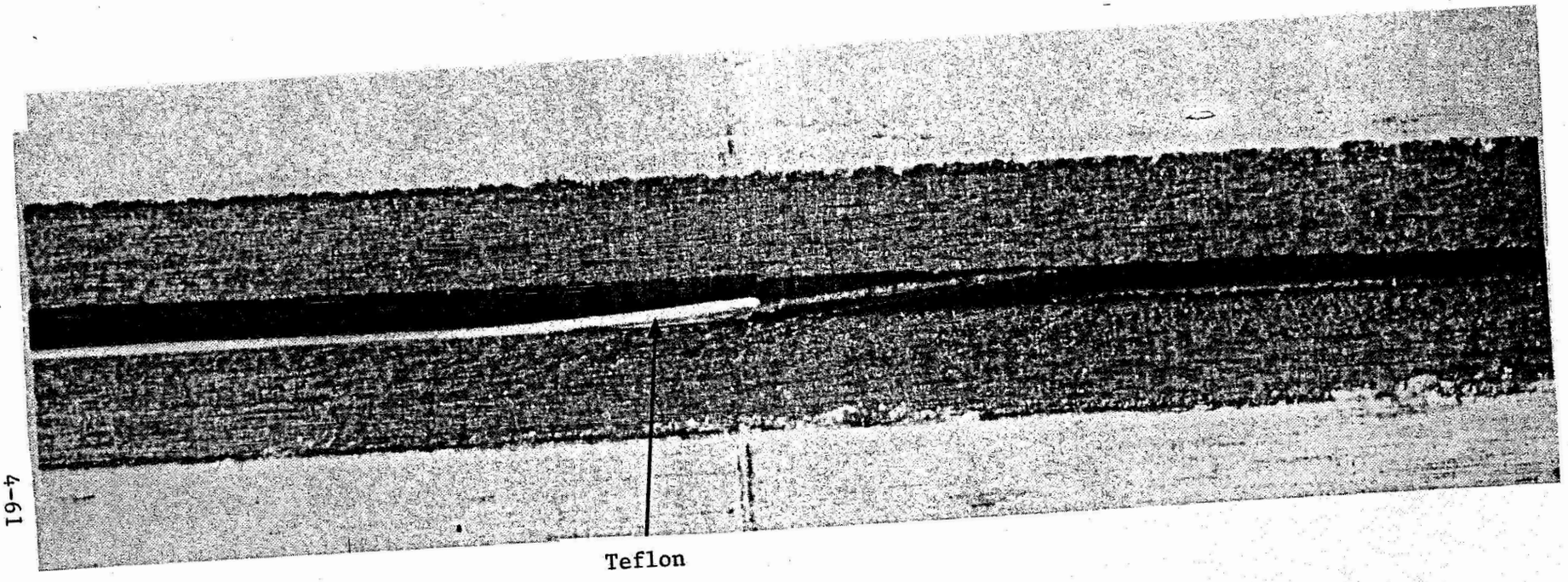


Figure 4-36: Closeup of DCB Specimen 21-5 Showing Crack Branching at Teflon Crack Starter.

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Figure 4 37: Closeup of DCB Specimen 38-2 Showing Crack Transition From Center of Laminate to Adhesive Bond Line.

specimen remains fixed while the lower beam is pulled downward producing a slight non-perpendicular load on the horizontal plane of the laminate, and as the crack extends this misalignment would increase.

4.7 EDGE DELAMINATION TESTS

Tensile tests were conducted on AS4/3502 and AS4/2220-1 laminates of two different layups to evaluate the NASA ST-2 Edge Delamination Tension test technique for toughness measurements. Specimens 1.5-inch wide by 10-inches long (Figure 4-38) were fabricated from each laminate. Ten specimens of each type were made, five of which were tested and five sent to NASA untested. After testing the five in our laboratory they too were sent to NASA for a post test analysis.

The overall test setup is shown in Figure 4-39 with a specimen mounted in hydraulic grips. Lexan inserts were used for gripping tabs. A four inch gage length extensometer was mounted as shown in Figure 4-40 in the center test section. Outputs from the extensometer and load cell were fed to an X-Y recorder located by the test machine. Load was applied at 0.00008 inches/sec. (0.002 mm/sec.) while visually observing both the X-Y plotter, for any deviation of the curve from a straight line, and/or edge delamination on the specimen. The objective was to find the onset of edge delamination, at which point the test, in most cases, was terminated. Additionally load, strain, and stroke data were taken by the computer. The X-Y plots, load-strain plots, specimen dimensional data, and observed notes are contained in Appendix B-8. Test results are summarized in Tables 4-17 through 4-20.

On both the $\pm 30^{\circ}$ and $\pm 35^{\circ}$ specimens of AS4/2220-1 delaminations were observed concurrently with deviations in the load-strain X-Y plots from a linear slope as shown in Figure 4-41. However, with specimens of both layups of AS4/3502 linearity deviation was not accompanied by an observable delamination. This is also illustrated in Figure 4-41 by the second curve

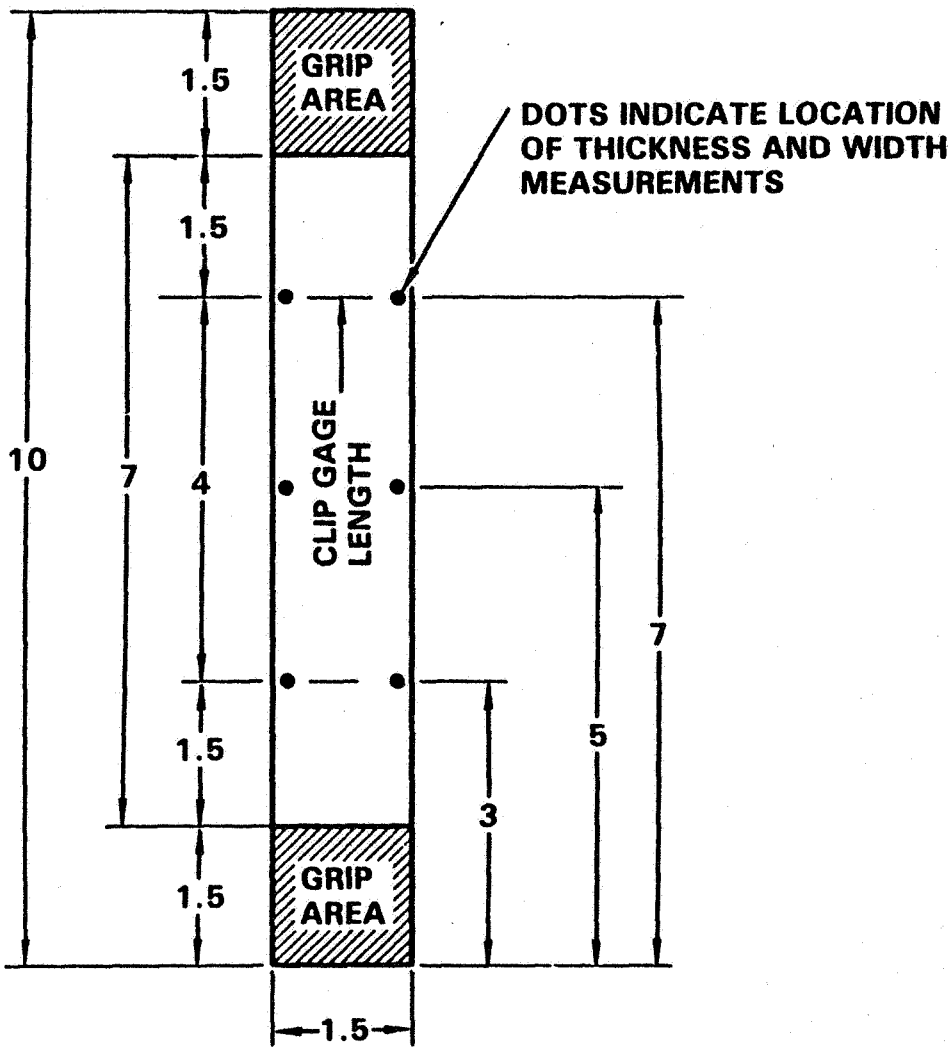


Figure 4-38: Edge Delamination Tension Test Specimen (Dimension Are In Inches).

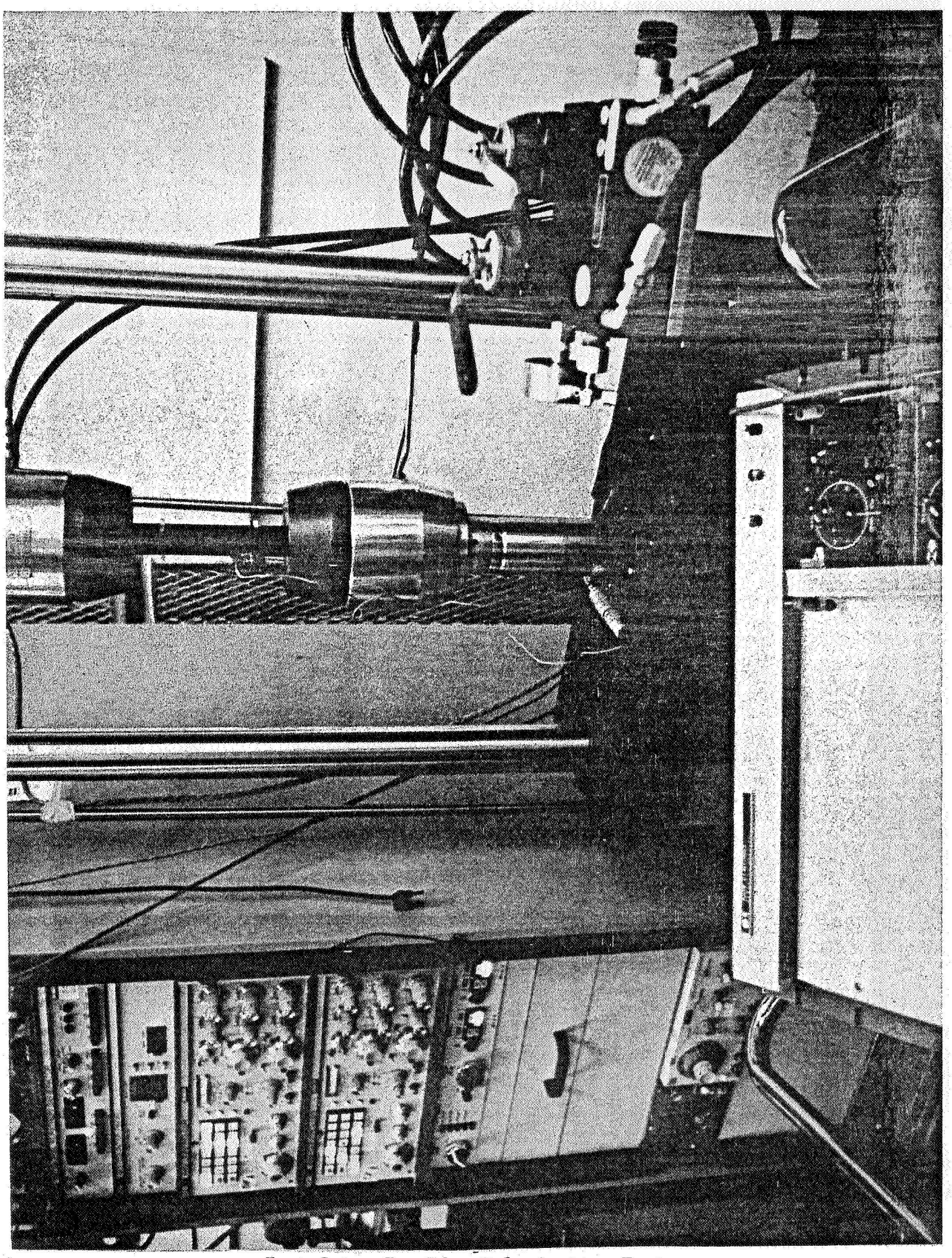


Figure 4-39: Test Setup For Edge Delamination Tests.

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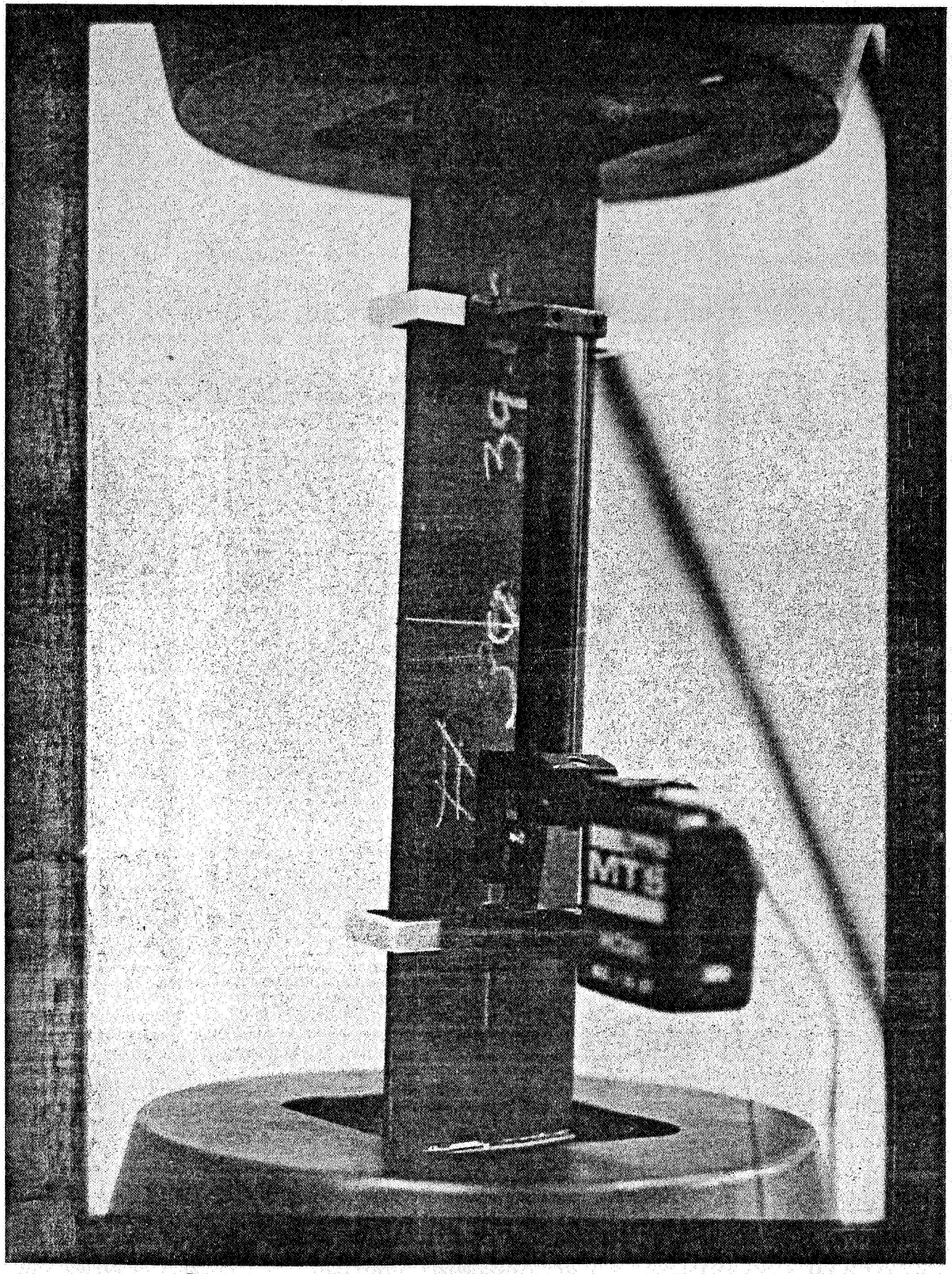


Figure 4-40: Closeup of 4-Inch Gage Length Extensometer Mounted on Edge Delamination Specimen.

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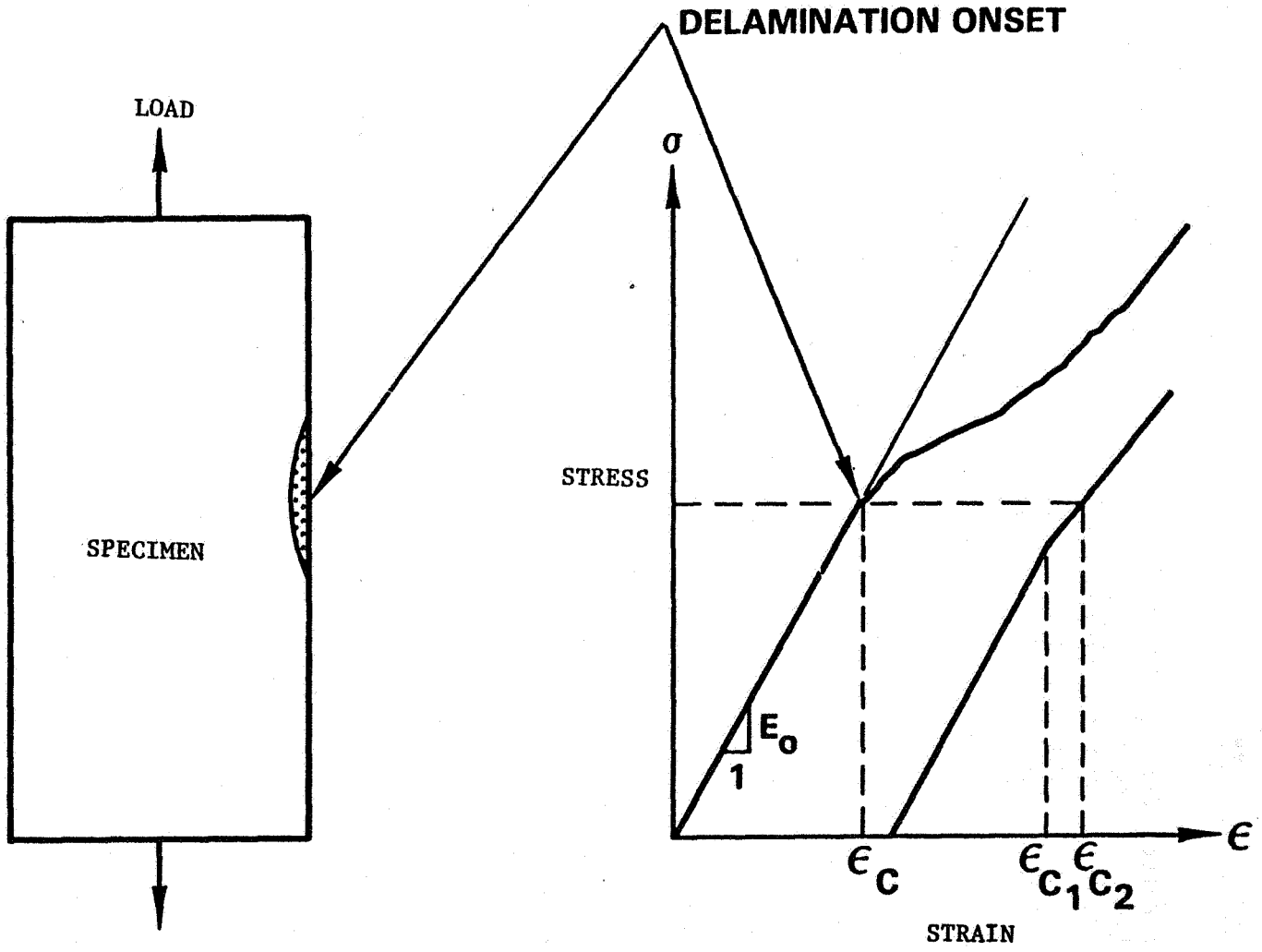


Figure 4-41: Critical G_c Determination.

TABLE 4.17 - AS4/3502 EDGE DELAMINATION TEST DATA

Laminate Orientation: $(\pm 35°/0°/90°)_S$
Laminate Resin Content: 27.1%
Test Condition: 75°F Dry

Coupon I.D.	Thickness (in.)	Width (in.)	Delamination Onset Strain (μin/in) ①	Delamination Onset Strain (μin/in) ②	Failure Strain (μin/in)	Tensile Modulus (msi)	Secant Modulus (msi)
20-1	0.040	1.506	4550	5539	③	9.94	-
20-2	0.039	1.503	4980	5542	③	10.30	-
20-3	0.039	1.506	5000	5304	③	10.22	-
20-4	0.039	1.506	4810	4810	11690	10.10	-
20-11	0.040	1.506	4900	5000	11010	9.97	-
AVERAGE			4848	5239	11350	10.11	-

① Strain at first deviation from linear stress-strain curve.

② Strain at first visible delamination.

③ Specimens not tested to failure.

TABLE 4.18 - AS4/2220-1 EDGE DELAMINATION TEST DATA

Laminate Orientation: $(\pm 35°/0°/90°)_S$
Laminate Resin Content: 29.6%
Test Condition: 75°F Dry

Coupon I.D.	Thickness (in.)	Width (in.)	Delamination Onset Strain (μin/in) ①	Delamination Onset Strain (μin/in) ②	Failure Strain (μin/in)	Tensile Modulus (msi)	Secant Modulus (msi)
40-1	0.043	1.498	6060	6060	⑥	8.94	-
40-2	0.044	1.497	6080	6080	⑥	8.76	-
40-3	0.044	1.497	5508	5508	⑥	8.70	-
40-4	0.045	1.497	6000	6000	13040	8.53	-
40-5	0.044	1.496	5370	5370	12225	8.99	-
AVERAGE			5804	5804	12633	8.78	-

① Strain at first deviation from linear stress-strain curve.

② Strain at first visible delamination.

③ E_{11} = 20.24 msi, ν_{12} = 0.3102. Reference 0° TENSION TEST DATA.

④ G_{12} = 0.70 mis. Reference ±45° TENSION TEST DATA.

⑤ E_{22} = 1.64 msi. Reference 90° TENSION TEST DATA.

⑥ Specimens not tested to failure.

TABLE 4.19 - AS4/3502 EDGE DELAMINATION TEST DATA

Laminate Orientation: $(\pm 30°_2/90°/\overline{90°})_S$
Laminate Resin Content: 27.8%
Test Condition: 75°F Dry

Coupon I.D.	Thickness (in.)	Width (in.)	Delamination Onset Strain (μin/in) ①	Delamination Onset Strain (μin/in) ②	Failure Strain (μin/in)	Tensile Modulus (msi)	Secant Modulus (msi)
19-1	0.054	1.511	2940	3400	③	8.40	-
19-2	0.054	1.511	2970	3250	③	8.30	-
19-3	0.054	1.511	3140	3240	③	8.19	-
19-4	0.055	1.510	2730	3168	③	8.54	-
19-5	0.054	1.510	3095	3095	③	8.40	-
AVERAGE			2975	3231		8.37	-

① Strain at first deviation from linear stress-strain curve.

② Strain at first visible delamination.

③ Specimens not tested to failure.

TABLE 4.20 - AS4/2220-1 EDGE DELAMINATION TEST DATA

Laminate Orientation: $(\pm 30°_2/90°/\overline{90°})_S$
Laminate Resin Content: 28.6%
Test Condition: 75°F Dry

Coupon I.D.	Thickness (in.)	Width (in.)	Delamination Onset Strain (μin/in) ①	Delamination Onset Strain (μin/in) ②	Failure Strain (μin/in)	Tensile Modulus (msi)	Secant Modulus (msi)
39-1	0.058	1.504	4675	4675	⑥	7.28	7.11
39-2	0.058	1.504	5140	5140	⑥	7.46	7.07
39-3	0.059	1.502	5075	5075	⑥	7.36	7.24
39-4	0.058	1.504	4526	4526	⑥	7.48	7.16
39-5	0.059	1.503	5170	5170	⑥	7.41	7.18
AVERAGE			4917	4917		7.40	7.15

① Strain at first deviation from linear stress-strain curve.

② Strain at first visible delamination.

③ E_{11} = 20.24 msi, ν_{12} = 0.3102. Reference 0° TENSION TEST DATA.

④ G_{12} = 0.70 msi. Reference °45° TENSION TEST DATA.

⑤ E_{22} = 1.64 msi. Reference 90° TENSION TEST DATA.

⑥ Specimens not tested to failure.

where ϵ_{C1} is the deviation point and ϵ_{C2} the point where the first delamination is observed. These different strain values are listed in Tables 4.17 and 4.19 where they differ by approximately 10%.

Of the five $\pm 35^{\circ}$ specimens, of both laminates tested, two were run to failure. These failure strains are listed in Tables 4.17 and 4.18, and the load-strain curves are contained in Appendix B-8.

4.8 FUEL LEAKAGE TESTS

Panels used for trial impact screening were selected for determining at what impact damage level fuel would seep through the laminate. Each panel (7 in. x 25 in.) contained four impacts at different energies. Initially AS4/3502 panels (see Section 4.2) with impact energies of 10, 15, 20 and 30 ft. -lb were selected for evaluation. The front and back surfaces of these panels are shown in Figures 4-5 and 4-6 where the visible damage ranges from barely visible to a 4 inch delamination. In these initial tests fuel pressure boxes, shown installed in Figure 4-42, were mounted so that the fuel was exposed on the impact side. This was done because at the higher impact energy levels the back surface damage extended into the fuel box contact zone, and a good pressure seal could not be obtained. On all subsequent tests the fuel boxes were mounted on the back surfaces as would be the service condition in a wet wing. Since leakage occurrred at the lower energy levels with minor back surface damage the sealing problem disappeared.

Figure 4-42 shows four fuel boxes mounted on two impacted panels, the impact side of the panels are in the right hand photo. Each chamber has a vent bleed line in the top which is opened during filling to assure that all air is expelled and fuel completely fills each box prior to pressurization. Fill lines are attached in the center of each box and go to a regulator for pressurizing with dry nitrogen. Shell Pella A with fluorescent dyes (see Section 3) was used as a simulated fuel.

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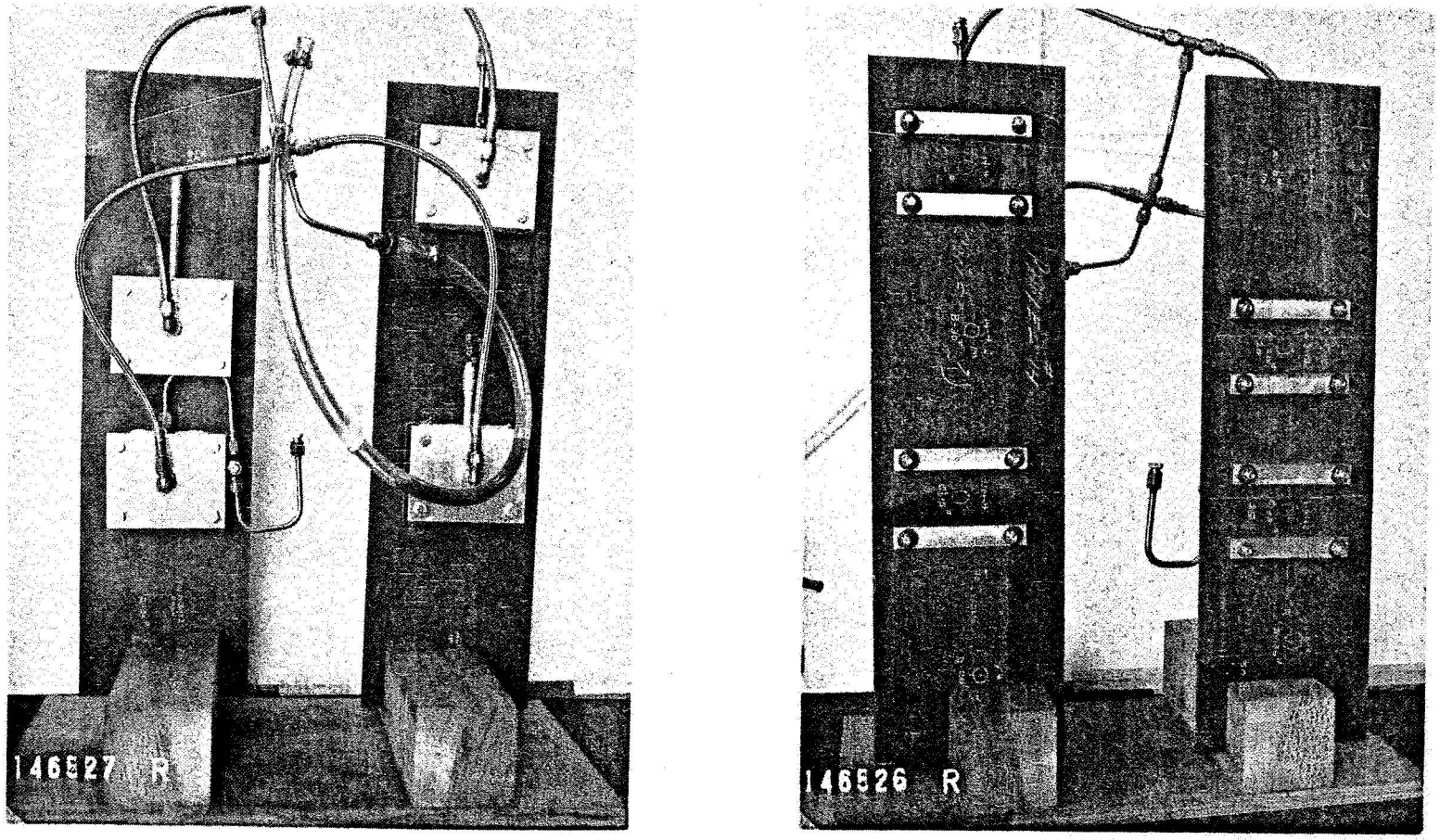


Figure 4-42: Fuel Leakage Test Setup Showing Boxes Mounted on Panel Back Surface From Impact. Seepage Is Visible at Each Impact in the Right Photo (Impact Side).

Table 4.21 summarizes the tests conducted to date. As shown the 30 ft.-lb. impact on specimen 14-2 (AS4/3502) leaked immmediately on application of 15 psi fuel prressure. At 20 ft-lb. impact specimen 14-3 leaked after one hour at 15 psi. The 10 and 15 ft-lb impacted samples were allowed to remain under 15 psi pressure overnight and by the next morning indicated leakage. The precise time leakage occurred was not observed but was less than 16 hours. Figures 4-43 and 4-44 show 10 ft-lb impacts that leaked within one hour at 5 and 10 psi respectively. Specimen 14-4 with a 15 ft-lb impact was ready for test on a Friday afternoon, but since no observers were available for the weekend, the chamber was filled with fuel, but not pressurized, and allowed to set over the weekend. By Monday morning leakage had occurred (Figure 4-45) with no pressure ever applied other than approximately the 1 inch fluid head in the chamber which is essentially zero pressure.

Specimens 1-3-13 (Celion/982) at 10 ft-lb and AS4/3502-48 at 10 ft-lb were initially pressurized to 10 psi and allowed to sit for 24 hours. No leaks were noted so the pressure was increased to 15 psi and allowed to sit for another 24 hours. Again no leaks were detected so the pressure was increased to 25 psi. Specimen AS4/3502-48 leaked after 1 1/4 hours at 25 psi while specimen 1-3-13 showed no evidence of leakage after 24 hours at which time the test was terminated.

Specimens 1-3-12 (AS4/2220) impacted at 20 and 25 ft-lb were pressurized to 5 psi and left to sit overnight. By the next morning both had leaked as shown in Figure 4-46.

A pressure box was attached to an undamaged 48-ply panel (34-1) of AS4/2220 and allowed to sit at 25 psi for 800 hours at room temperature to determine if any leakage would occur through a laminate with no cracks or delaminations. Examination of the panel after 800 hours revealed no evidence of fuel on the opposite surfce.

TABLE 4.21. FUEL LEAKAGE TEST RESULTS

Specimen ID	Material	Impact Energy ft-lb	Delamination Area $in.^2$	Pressure psi	Surface	Time to Leak hours
14-1	AS4/3502	10	1.30	10	B	1
14-2	AS4/3502	15	1.70	15	F	<16
14-2	AS4/3502	30	2.05	15	F	0
14-3	AS4/3502	10	1.60	15	F	<16
14-3	AS4/3502	20	2.40	15	F	1
14-4	AS4/3502	10	1.40	5	B	1
14-4	AS4/3502	15	1.60	0	B	<72
1-2-12	AS4/2220	10	0.84	10	B	3-1/4
1-3-12	AS4/2220	20	2.05	5	B	<22
1-3-12	AS4/2220	25	2.89	5	B	<22
1-3-13	Celion/982	10	0.06	25 ①	B	No Leak ②
AS4/3502-48	AS4/3502	10	1.72	25 ①	B	1-1/4
1-3-13	Celion/982	20	1.63	5	B	8 < 24
1-3-13	Celion/982	25	3.44	5	B	8 < 24
1-3-13	Celion/982	30	5.42	10 ③	B	2
34-1	AS4/2220	None	None	25	B	No Leak ④

① 24 hours at 20 psi no leak, 24 hours at 15 psi no leak

② After 24 hours

③ 24 hours at 5 psi no leak, increased to 10 psi

④ 800 hours exposure

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Figure 4-43: Impact Side Leakage of a 47-Ply AS4/3502 Panel Impacted At 10 Ft.- Lbs. With a Fuel Pressure of 5 psi.

Figure 4-44: Impact Side Leakage of a 47-Ply AS4/3502 Panel Impacted At 10 Ft.- Lbs. With a Fuel Pressure of 10 psi.

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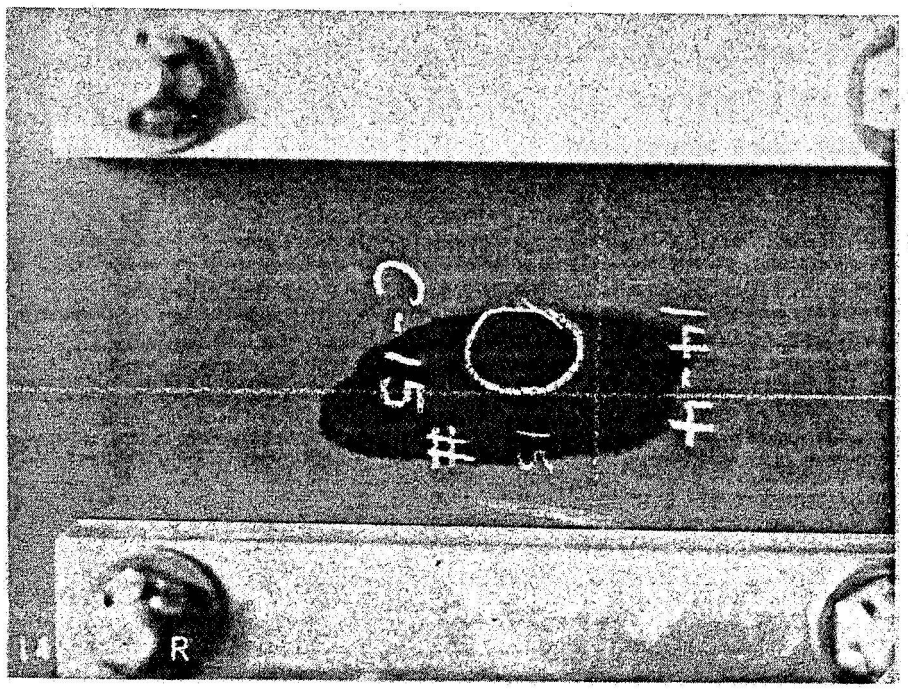


Figure 4-45: Impact Side Leakage of 47-Ply AS4/3502 Panel Impacted at 25 Ft.-Lb. at Approximately Zero Fuel Pressure.

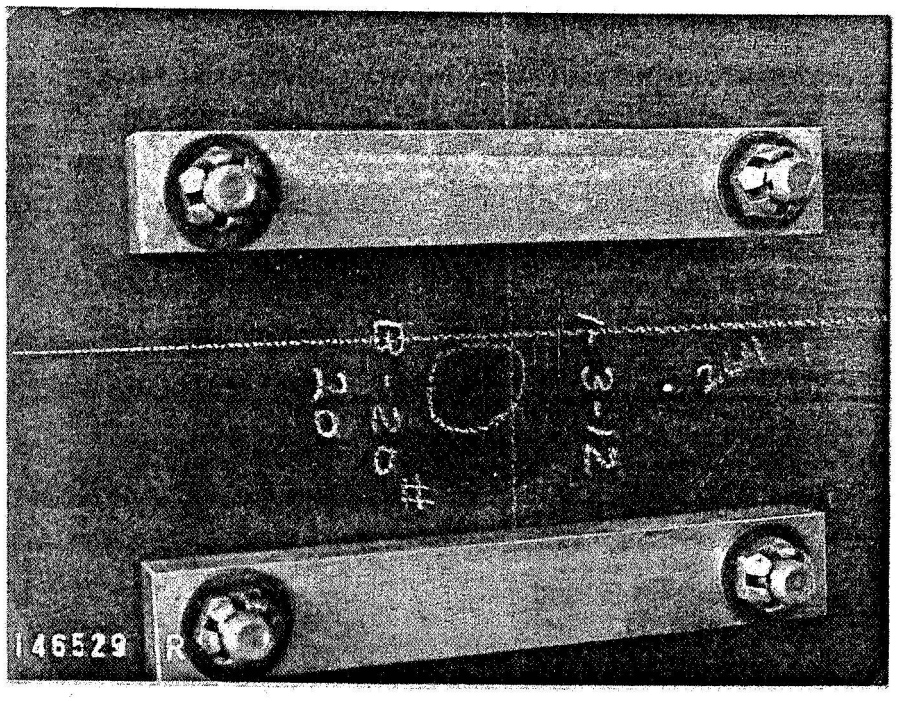


Figure 4-46: Impact Side Leakage of 48-Ply AS4/2220 Panel Impacted at 20 Ft.-Lb. With a Fuel Pressure of 5 psi.

Fuel leakage was so rapid through the 47-ply AS4/3502 panels sectional micrographs were made of 10, 15, 20 and 30 ft-lb impact areas after the leakage tests were concluded to visually ascertain the damage and how it would provide leakage channels through the laminate. Figures 4-47 through 4-50 shows 10X and 25X views of the impact area of the four energy levels and the extent of internal cracking which is extensive enough for fuel to readily channel through the laminate. In these figures the full extent of delamination, particularly near the specimen surface ,is difficult to see because of infiltration of mounting resin into open delaminations during the vacuum resin mounting operation. The resin is of a similar gray shade to the laminate and only close inspection can resolve which is which. In Figure 4-50 the filling problem is particularly acute but is more apparent due to the large delaminations. These sectional micrographs verify that while external visual examination may not reveal impact damage sufficient internal damage may have occurred to permit serious fuel leakage through a laminate skin.

4.9 MULTISPAN SHORT BEAM SHEAR TESTS

Multispan short beam shear tests were performed to evaluate the technique as a possible simple, inexpensive way to generate comparisons of the impact resistance of competing materials. The test models in two dimensions, the local laminate deformations under impact loading.

Test geometry is shown in Figure 4-51. It consists of seven 0.500 inch diameter half-cylinder loading points one inch long and one inch apart. These are affixed to 1 x 1 x 4 inch steel bars by screws. The fixture is placed in an MTS hydraulic test machine for loading at a constant 0.050 in/min. loading rate through a ball bearing on the top bar. The bottom bar is placed on flat ground plate mounted on the machine jack head. Specimens are inserted between the pins and aligned by hand. Specimens are 1.00 inch wide by 4.00 inch long and approximately 0.25 inch thick. Load is applied until a drop in the load-deflection curve is noted. In these tests that

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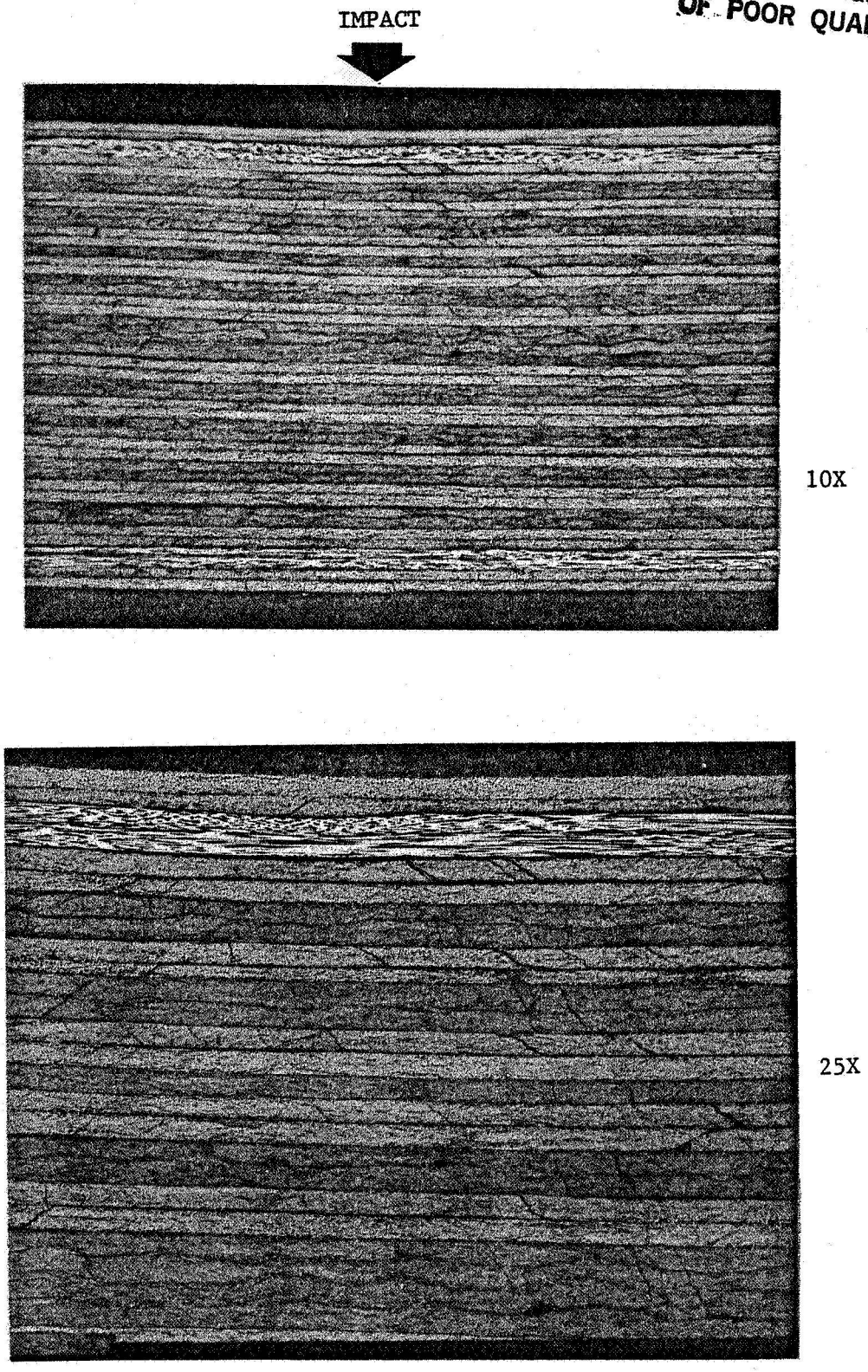


Figure 4-47: Sectional Micrographs of Specimen 14-3 Impacted at 10 Ft.-Lbs.

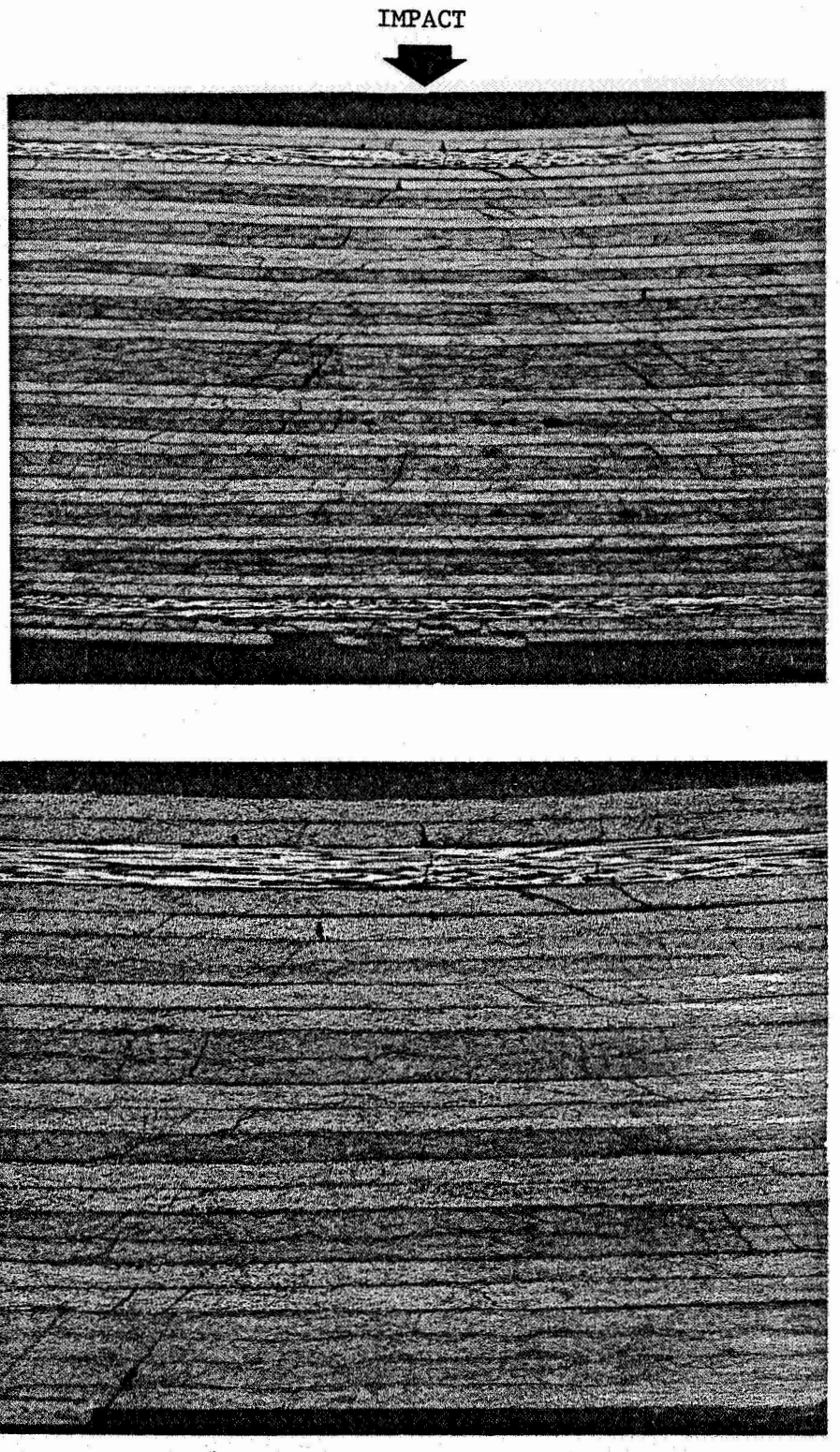


Figure 4-48: Sectional Micrographs of Specimen 14-2 Impacted At 15 Ft.-Lbs.

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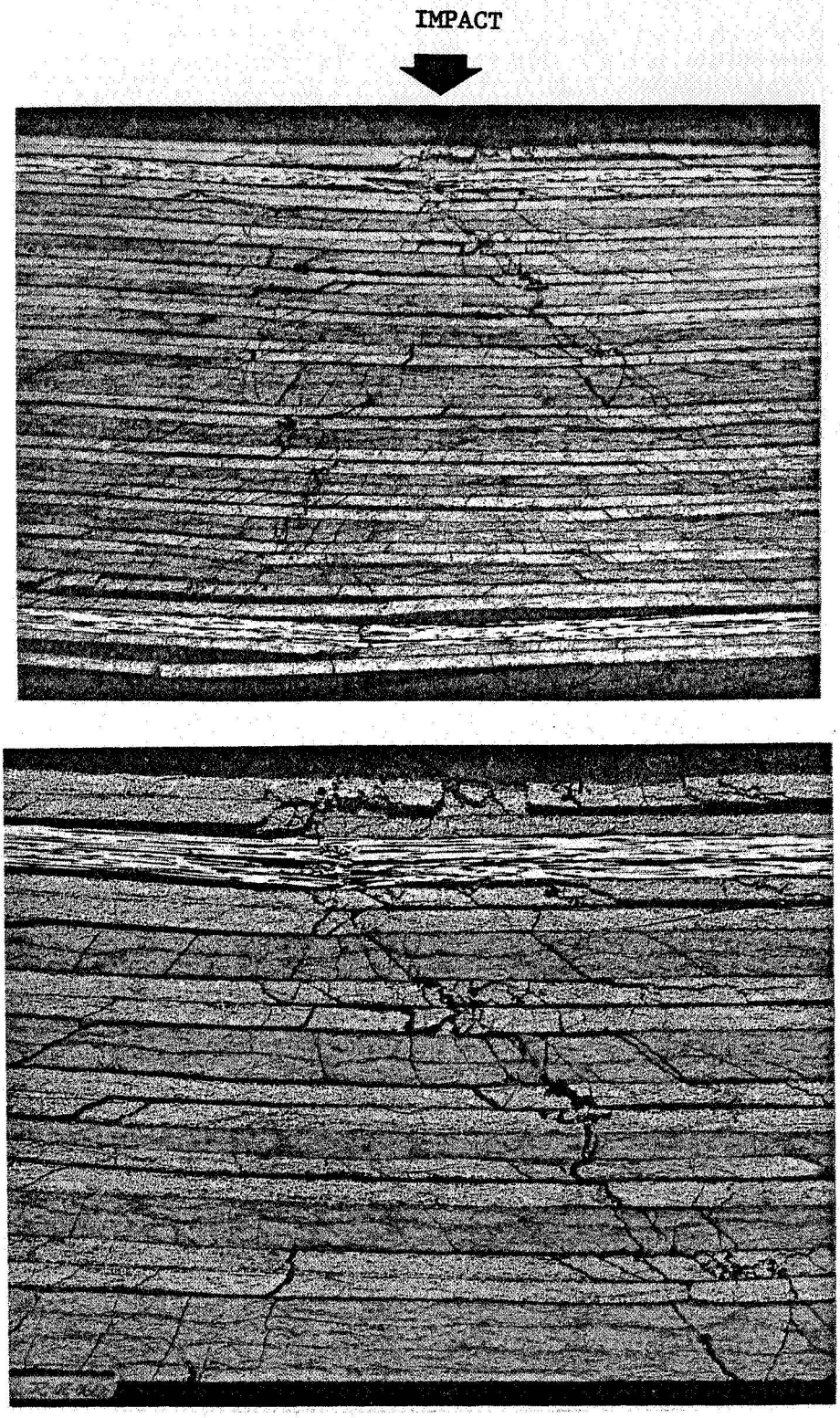
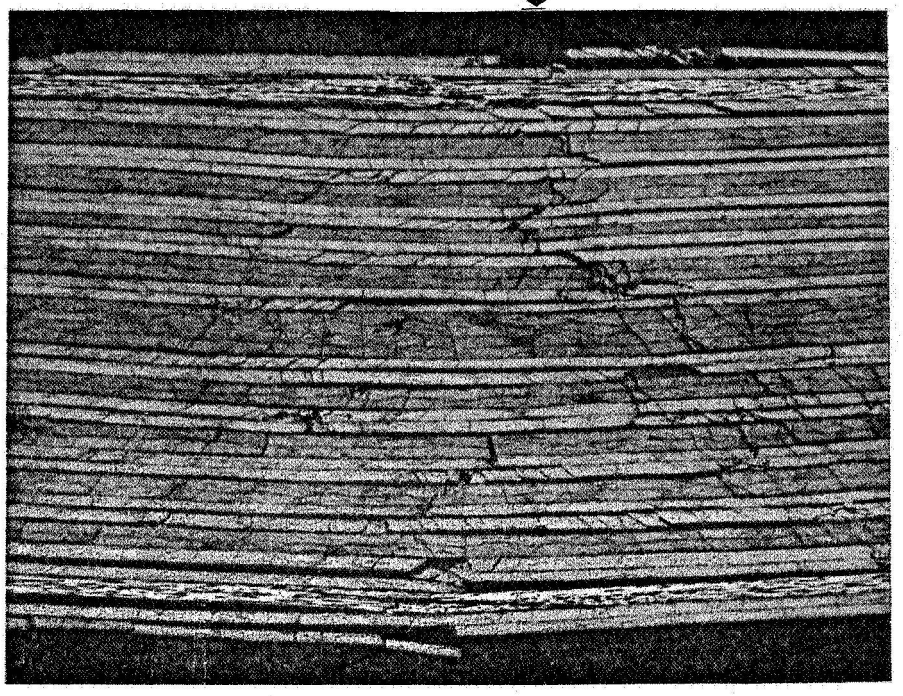


Figure 4-49: Sectional Micrograph of Specimen 14-3 Impacted At 20 Ft.-Lbs.

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25X

Figure 4-50: Sectional Micrographs of Specimen 14-2 Impacted At 30 Ft.-Lbs.

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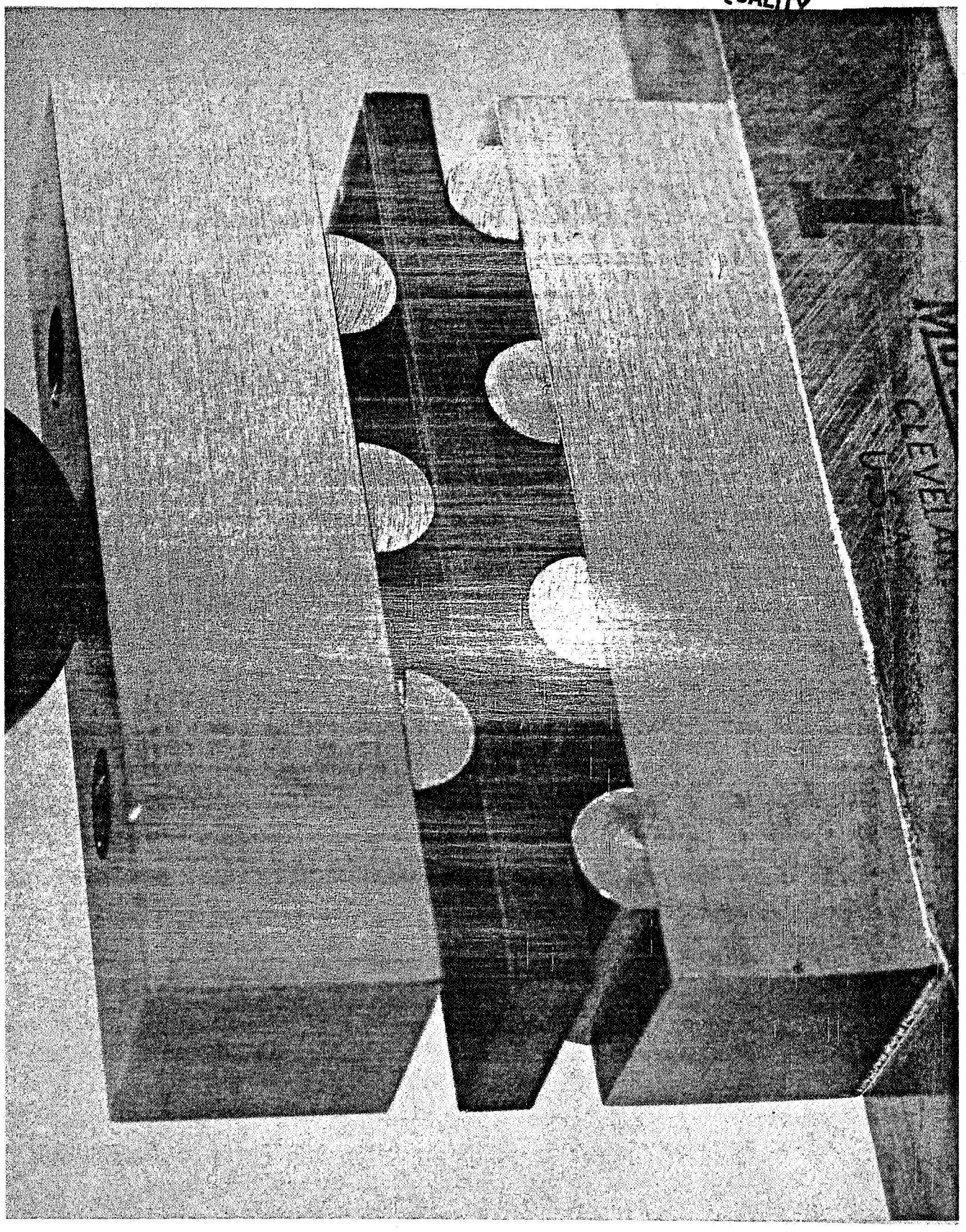


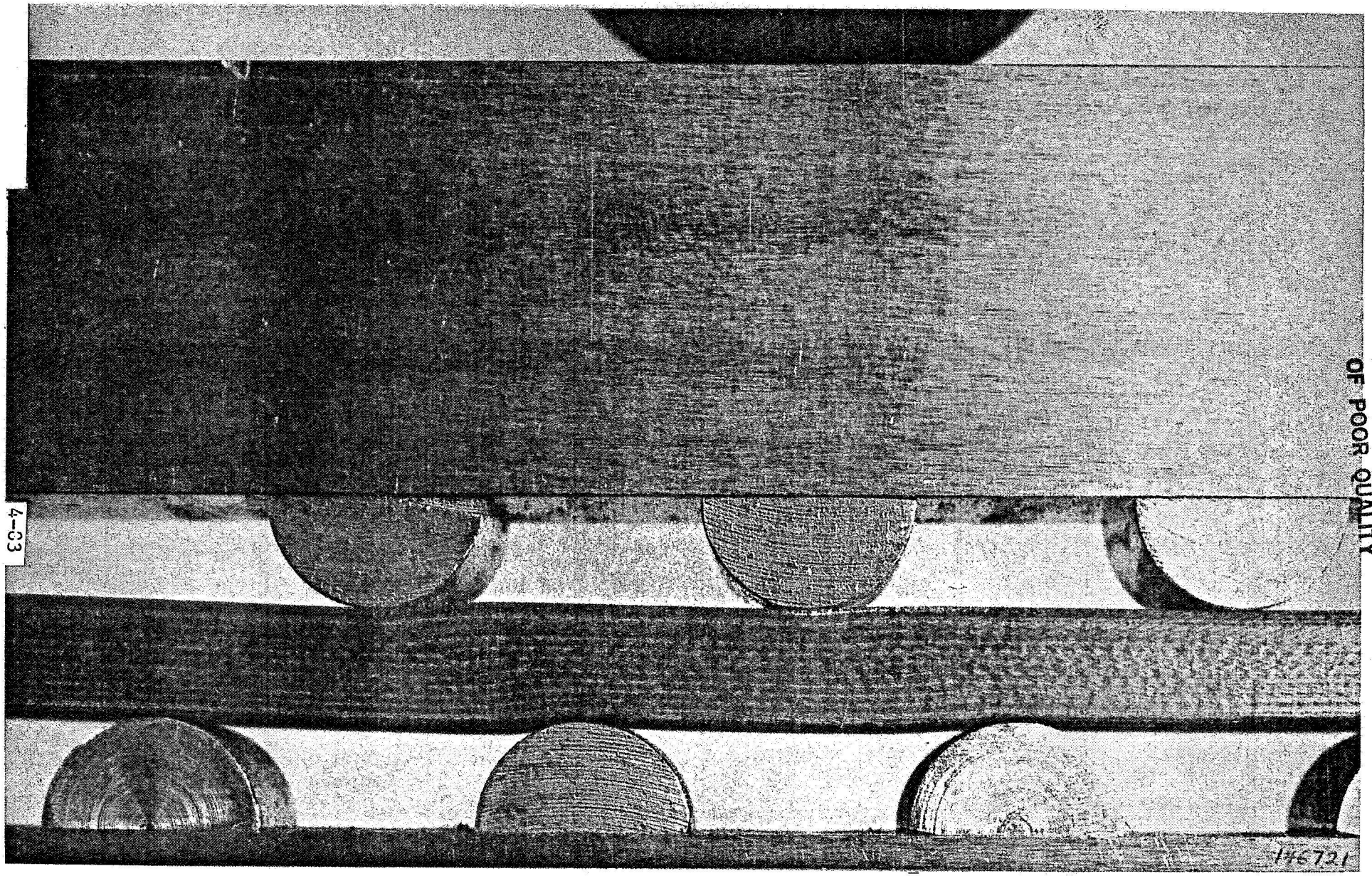
Figure 4-51: Multispan Short Beam Shear Test Set-up In The 7-Pin Configuration.

point was coincident with first visible crcking. A typical failure of the $(\pm 45\ 90_2(\pm 45\ 0_2)_5)_s$ laminate is shown in Figure 4-52. It is characterized by fractures running diagonally from an upper pin to a lower pin. In this layup the 90° fibers run longitudinally. Cracking goes across the 0° plies (0° fibers paralled to loading pins) at a 45° angle, delaminates at the -45° to 0° interface, and to a lesser extent delaminates at the $+45^\circ$ to 90° interface. Test results are summarized in Table 4.22. The AS4/2220-1 specimens failed at a higher average load (-5687 lbs.) than the AS4/3502 specimens (-5230 lbs.). This indicates that the AS4/2220-1 material will exhibit less damage due to impact than the AS4/3502. This is also verified by the results in Section 4.2.

One test each of AS4/3502 and AS4/2220-1 were run on specimens 5 inches long to evaluate and overhang effects, none were noted.

A second group of specimens from an AS4/3502 panel (101A) of a different layup $(\pm 45\ 90\ \pm 45\ 0\ \pm 45_2\ 90\ \pm 45\ 0\ \pm 45)_s$ were tested with both the 7 pin and 5 pin fixture configuration. Specimens were cut in both the 0° and 90° orientation. Test results are shown in Table 4.23. Typical failure modes for the 7 pin 90° longitudinal layup are shown in Figure 4-53. Larger delaminations occur in the layup than the previous one with less cracking. Similar cracking and delamination was observed with 5 pin loading as shown in Figures 4-54 and 4-55. The specimen in Figure 4-54 has longitudinal 0° plies, and the specimen in Figure 4-55 has longitudinal 90° plies. There is no significant difference in the failure loads of the two orientations.

Appendix B-9 contains load-deflection curves for all the beam tests, specimen geometric measurements, fixture orientation, and failure data. It was noted that specimens always failed toward one end of the test fixture. Checks of the fixture indicated that the bearing plane of the pins was within ± 0.0002 in. The 1 x 1 x 4 blocks were within ± 0.001 in. Specimen dimensions however had major tapers of up to 0.010 in. over the 4 in. length and 0.004 in. from side to side in the 1.0 in. width direction. These detailed



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Figure 4-52: Failure Mode of 48-Ply AS4/2220-1 Specimen With 90^{o} Orientation in the Longitudinal Axis.

TABLE 4.22 MULTISPAN SHORT BEAM SHEAR TEST RESULTS

Laminate Orientation: $(\pm 45\ 90_2\ (\pm 45\ 0_2)_5)_S$ ①

Laminate	Specimen I.D.	Loading Config.	Thick. (in.)	Width (in.)	Area ($in.^2$)	Length (in.)	Max. Load (lbs)
AS4/2220-1	34-7-1	7 Pin	0.244	0.998	0.244	4.0	-5190
AS4/2220-1	34-7-2	7 Pin	0.255	1.002	0.256	4.0	-5504
AS4/2220-1	34-7-3	7 Pin	0.264	1.000	0.264	4.0	-6099
AS4/2220-1	34-7-4	7 Pin	0.239	1.003	0.241	4.0	-5915
AS4/2220-1	34-7-5	7 Pin	0.249	0.997	0.249	4.0	-5474
AS4/2220-1	34-7-6	7 Pin	0.261	0.999	0.260	5.0	-5942
							Avg. -5687
AS4/3502	15-7-1	7 Pin	0.264	0.999	0.264	4.0	-4668
AS4/3502	15-7-2	7 Pin	0.265	1.004	0.266	4.0	-5649
AS4/3502	15-7-3	7 Pin	0.264	1.005	0.265	4.0	-5209
AS4/3502	15-7-4	7 Pin	0.264	1.006	0.266	4.0	-5479
AS4/3502	15-7-5	7 Pin	0.264	1.005	0.265	4.0	-5059
AS4/3502	15-7-6	7 Pin	0.263	0.999	0.263	5.0	-5315
							Avg. -5230

① Specimen longitudinal fiber orientation 90^o

TABLE 4.23 MULTISPAN SHORT BEAM SHEAR TEST RESULTS

48 Plies AS4/3502

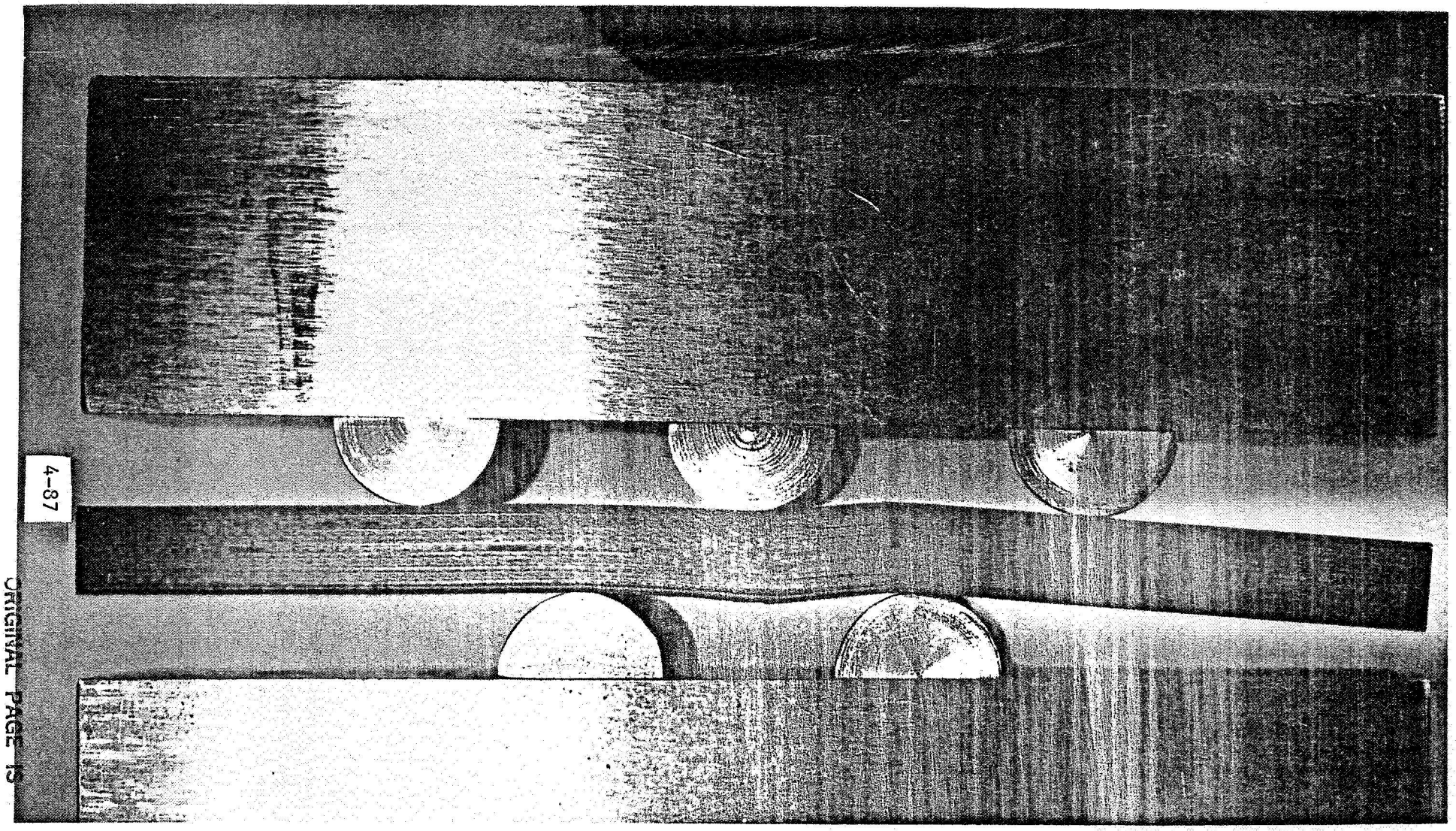
Laminate Orientation: $(\pm 45 90 \pm 45 \pm 45_2\ 90 \pm 45 \pm 45_2\ 90 \pm 45 \pm 45)_S$

Specimen I.D.	Loading Config.	Thick. (in.)	Width (in.)	Area$_2$ (in.^{2})	Max. Load (lbs.)	Longit Fiber Orientation	Fixture ① Orientation
101A-1	7 Pin	0.246	1.000	0.246	-.7751	90°	-
101A-2	7 Pin	0.246	1.001	0.246	-.7051	90°	TR/BR
101A-3	7 Pin	0.257	1.002	0.258	-.6909	90°	TR/BL
101A-4	7 Pin	0.252	1.002	0.253	-.8751	90°	TR/BR
101A-5	7 Pin	0.259	1.002	0.260	- 7881	90°	TR/BL
101A-6	7 Pin	0.253	1.002	0.254	- 9040	90°	TR/BR
101A-8	5 Pin	0.250	1.002	0.251	- 5266	90°	TR/BR
101A-9	5 Pin	0.242	1.004	0.243	- 4817	0°	TR/BR
101A-10	5 Pin	0.252	1.000	0.252	- 4893	0°	TR/BL
101A-11	5 Pin	0.257	1.004	0.258	- 5260	0°	TR/BL
101A-12	5 Pin	0.251	1.000	0.251	- 4895	0°	TR/BR
101A-13	5 Pin	0.258	1.005	0.259	- 5351	0°	TR/BL

① Orientation of top loading bar to bottom loading bar. TR = top right, BL = bottom left

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Figure 4-53: Failure Modes on Specimens 101A-4 and 101A-6. Longitudinal Bright Plies Are 90^{o} Plies. Specimen Material is AS4/3502.



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Figure 4-54: Failure Mode of Specimen 101A-12. The Six Bright Plies Are 0^{o} Plies.

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Figure 4-55: Failure Mode of Specimen 101A-8. The Six Bright Longitudinal Plies are 90^{o} Plies.

dimensions are listed in Appendix B-9. During the tests on the 101A panel (Table 4.23) the loading bars were indexed as to top-right, bottom-right, etc. then the upper loading bar was rotated 180^{o} to give top-right, botttom-left and then back to the original position. In the TR/BR position failures always occurred on the left side, in the TR/BL position failures always occurred on the right side, all other variables were held constant. Table 4.23 lists these orientations per test; no apparent difference was noted in failure load. Also the failures did not occur on the thinner end as would be expected, only on one end of the fixture. Since the load was applied through a spherical ball on the top beam which is on center with the center pin of 3, and all pins were 1.000 $\pm$ 0.002 inches apart the preferential failure location has not been explained.

To aid in understanding the observed failure modes an analysis was performed on Lockheed IRAD program "Fracture of Engineering Materials" by P.E. Sandorff for specimens with multiple loading points and compared to the standard 3 pin short beam shear specimen configuration. The analysis is presented in Appendix B-10.

APPENDIX A-1

AS4/2220-1 LAMINATE DATA

Description								QA Data				Process Data									
I.D.	No. Plies	% 0°	% ±45°	% 90°	Length (in.)	Width (in.)	Initial Resin Content (4) (%)	NDI "C"Scan	Resin Content (%)	Thickness Per Ply (mils)	Interlam Tension (psi)	Cure Cycle Req.	No. Peel	Bleeder 120	Plies 181	Time to 210°F (min)	Rate (°F/min)	Time to 225°F (min)	Rate to 225°F (°F/min)	Time to 80 psi (min)	Bleeder Resin Content (%)
1A	48	25	50	25	26	24	35	OK	33.9	5.57	2633	A	1	0	2	115	0.87	173	0.66	192	21.7
4	48	25	50	25	26	24	35	BAD	34.7	5.60	(3)	B	1	0	2	66	1.5	86	1.34	195	21.1
5	48	25	50	25	26	24	35	BAD	35.0	5.64	(3)	B	1	0	2	66	1.5	86	1.34	195	23.9
10	96	25	50	25	26	24	34	BAD	(3)	5.62	(3)	A	1	0	5	103	0.92	155	0.71	255	(3)
10A	96	25	50	25	26	24	34	OK	36.0	5.49	2110	A	1	0	5	110	0.86	155	0.71	163	14.0
11	48	25	50	25	26	24	34	BAD	(3)	5.65	(3)	A	1	0	2	93	1.0	155	0.71	255	11.0
11A	48	25	50	25	26	24	34	OK	33.8	5.54	2597	A	1	0	2	113	1.0	136	0.96	133	23.8
12	48	25	50(5)	25	80	30	34	OK	34.3	5.49	2783	A	1	0	2	114	1.0	137	0.95	133	24.4
34	48	41.7	50	8.3	68	24	36	OK	34.5	5.54	2295	A	1	0	2	103	1.1	113	1.11	132	30.3
35	48	41.7	50	8.3	68	24	36	OK	35.0	5.51	2658	A	1	0	2	103	0.97	113	1.02	132	29.6
36	48	41.7	50	8.3	68	24	36	OK	35.8	5.54	2170	A	1	0	2	97	1.2	136	0.96	123	27.7
37	12	0	100	0	21	12	35	OK	29.8	5.21	2050	A	2	1	0	72	1.5	93	1.34	115	42.3
38	12	100	0	0	30	26	35	OK	30.8	4.83	2062	A	1	1	0	84	1.3	98	1.28	115	29.7
39	11	0	72.7(1)	27.3	36	16	35	OK	28.6	5.57	2108	A	1	1	0	68	1.6	89	1.40	115	40.8
40	8	25	50 (2)	25	36	16	35	OK	29.6	5.42	2253	A	1	1	0	63	2.0	92	1.52	115	38.4
41	48	25	50 (5)	25	24	30	37	OK	30.5	5.48	2808	A	1	0	2	76	1.4	96	1.25	100	(3)
QA1	32	25	50	25	24	24		BAD	(3)	(3)	(3)	C	2	1	1	--	--	--	--	--	(3)
QA2	32	25	50	25	24	24		OK	34.5	5.4	(3)	A	2	1	1	--	--	--	--	--	(3)

BATCH 2029 AND BATCH 2163

(1) ±30°
(2) ±35°
(3) Not available.
(4) Calculated from cert. data.
(5) Unidirectional material used.

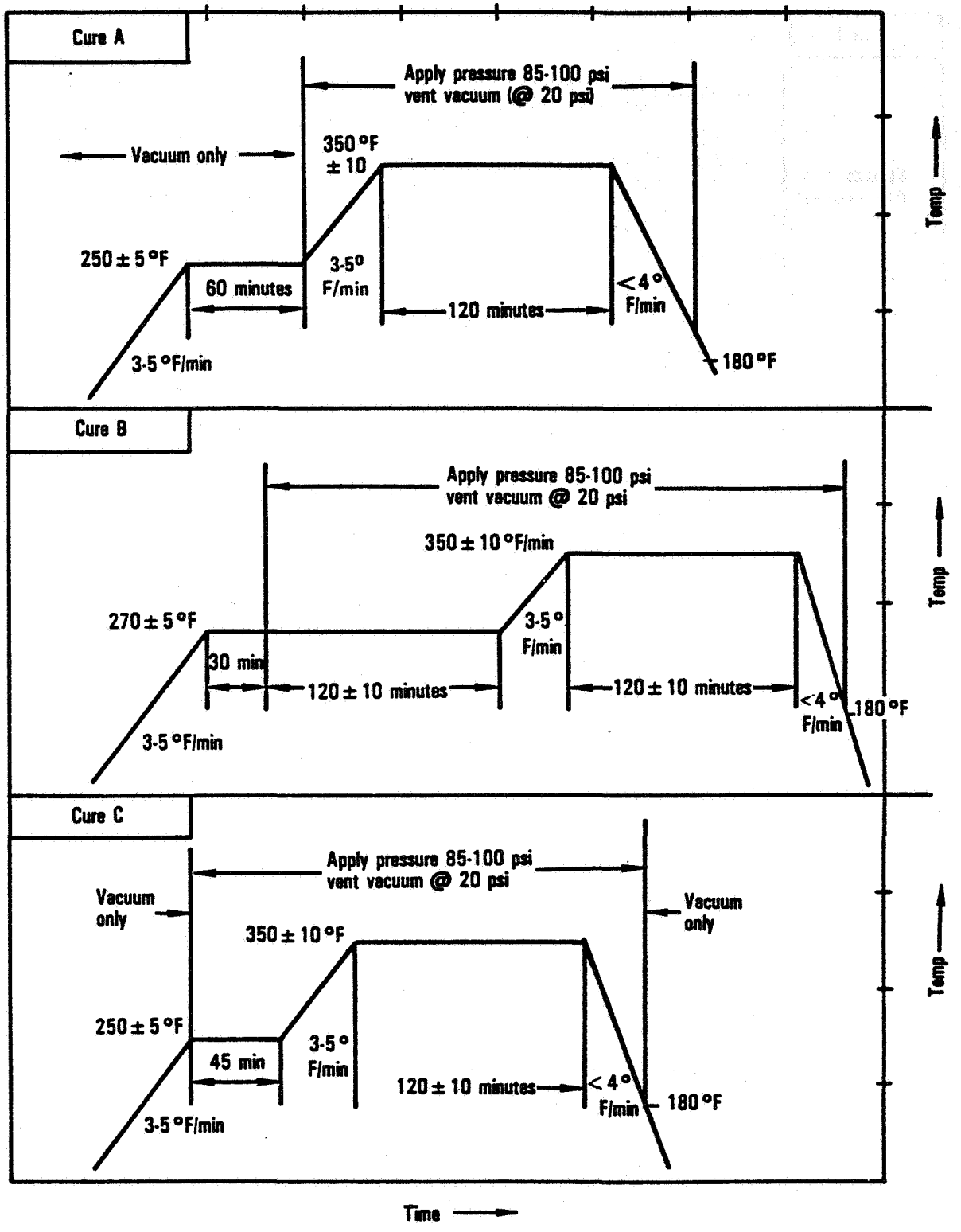
AS4/3502 LAMINATE DATA

Description								QA Data				Process Data										
I.D.	No. Plies	% 0°	% ±45°	% 90°	Length (in.)	Width (in.)	Initial Resin Content (6) (%)	NDI "C"Scan	Cured Resin Content (%)	Thickness Per Ply (mils)	Interlam Tension (psi)	Cure Cycle Req.	No. Peel	Bleeder 120	Plies 181	Time to 230°F (min)	Rate (°F/min)	Time to 250°F (min)	Time to 270°F/(min)	Rate to Dwell (°F/min)	Time to 80 psi (min)	Bleeder Resin Content (%)
1	48	25	50	25	26	24	37	OK	29.7	5.35	2270	A	1	0	5	90	1.2	160	(3)	0.81	238	35.8
2	48	25	50	25	26	24	37	OK	29.7	5.39	1900	A	1	0	5	90	1.2	160	(3)	0.81	238	36.4
3	48	25	50	25	26	24	37	OK	28.9	5.50	1960	A	1	0	5	90	1.1	160	(3)	0.81	238	30.0
84	48	25	50	25	26	24	39	OK	34.9	5.66	(5)	B	1	0	5	74	1.6	97	130	1.2	163	27.3
85	48	26	50	25	26	24	39	BAD	32.0	5.64	1298	B	1	0	5	90	1.6	120	160	1.0	195	31.1
8	96	25	50	25	26	24	39	OK	37.2	5.65	1425	B	1	0	11	84	1.5	110	144	1.2	163	24.7
9	96	25	50	25	26	24	39	BAD	33.9	5.26	2938	B	1	0	11	85	1.7	115	140	1.3	130	25.6
14	47	40.4	51.1	8.5	68	24	37	BAD	33.3	5.31	1473	B	1	0	5	64	2.3	80	120	1.5	110	30.3
15	48	41.7	50	8.3	68	24	37	BAD	35.1	5.54	2142	B	1	0	5	56	2.4	70	110	1.6	135	31.7
16	48	41.7	50	8.3	68	24	37	OK	35.1	5.84	2283	B	1	0	5	60	2.2	90	135	1.3	118	30.7
17	12	0	100	0	21	12	38	OK	31.5	5.42	2408	B	1	0	1	42	3.1	55	120	1.4	118	30.9
19	11	0	73(1)	27	36	16	36	OK	27.8	5.18	1827	B	1	0	2	50	2.5	70	130	1.3	130	26.9
20	8	25	50(2)	25	36	16	36	OK	27.1	5.00	1990	B	1	0	2	38	3.3	62	100	1.6	130	31.3
21	12	100	0	0	30	26	36	OK	28.4	4.92	2353	B	2	0	1	60	2.2	80	140	1.2	135	28.4
22	48	41.7	50	8.3	40	24	39	BAD	32.2	5.52	1403	B	1	0	5	70	1.9	100	140	1.2	160	32.8
24	20	10	80	10	40	24	38	OK	30.5	5.70	2567	B	1	0	2	60	2.2	88	135	1.3	118	32.6
25	20	10	80.	10	40	24	38	OK	29.0	5.95	2450	B	1	0	2	54	2.5	70	110	1.6	135	33.1
26	20	10	80	10	40	24	38	OK	26.8	5.35	2725	B	1	0	2	55	2.6	68	90	2.1	110	33.6
27	20	10	80	10	40	24	38	OK	29.6	5.40	2317	B	1	0	3	50	2.4	80	130	1.2	158	30.7
28	28	21.4	71.4	7.2	40	24	38	OK	28.4	5.50	2142	B	1	0	3	50	2.4	80	130	1.2	158	32.2
29	28	21.4	71.4	7.2	40	24	38	OK	29.3	5.68	2650	B	1	0	3	55	2.6	68	90	2.1	110	32.0
30	48	41.7	50	8.3	40	24	39	OK	30.9	5.60	2258	B	1	0	6	100	1.4	130	200	0.90	195	28.8
31	48	41.7	50	8.3	40	24	39	BAD	32.5	5.73	1903	B	1	0	5	90	1.4	120	200	0.82	195	30.3
QA1	32	25	50	25	24	24	40	BAD	36.2	5.69	(5)	A	3	0	0	57	2.4	68	(3)	2.4	130	(5)
QA2	32	25	50	25	24	24	40	BAD	35.8	6.09	(5)	A	2	1	0	52	2.0	65	(3)	2.0	135	(5)
QA3	32	25	50	25	24	24	40	OK	29.2	5.19	(5)	A	2	1	2	55	2.0	70	(3)	2.0	152	(6)
101	48	12.5	75	12.5	68	24	39	BAD	34.8	5.38	(5)	C	2	0	6	80	1.7	130	160	1.1	130	28.0
101A	48	12.5	75	12.5	68	24	39	BAD	34.6	5.82	2377	B	2	0	6	45	2.8	50	(4)	3.3	85	(5)
102	48	12.5	75	12.5	40	24	39	BAD	31.9	5.44	3050	C	2	0	6	80	1.7	130	160	1.1	130	29.6
104	48	41.7	50	8.3	40	24	39	BAD	31.4	5.42	2533	C	2	0	6	80	1.6	130	160	1.0	130	29.8

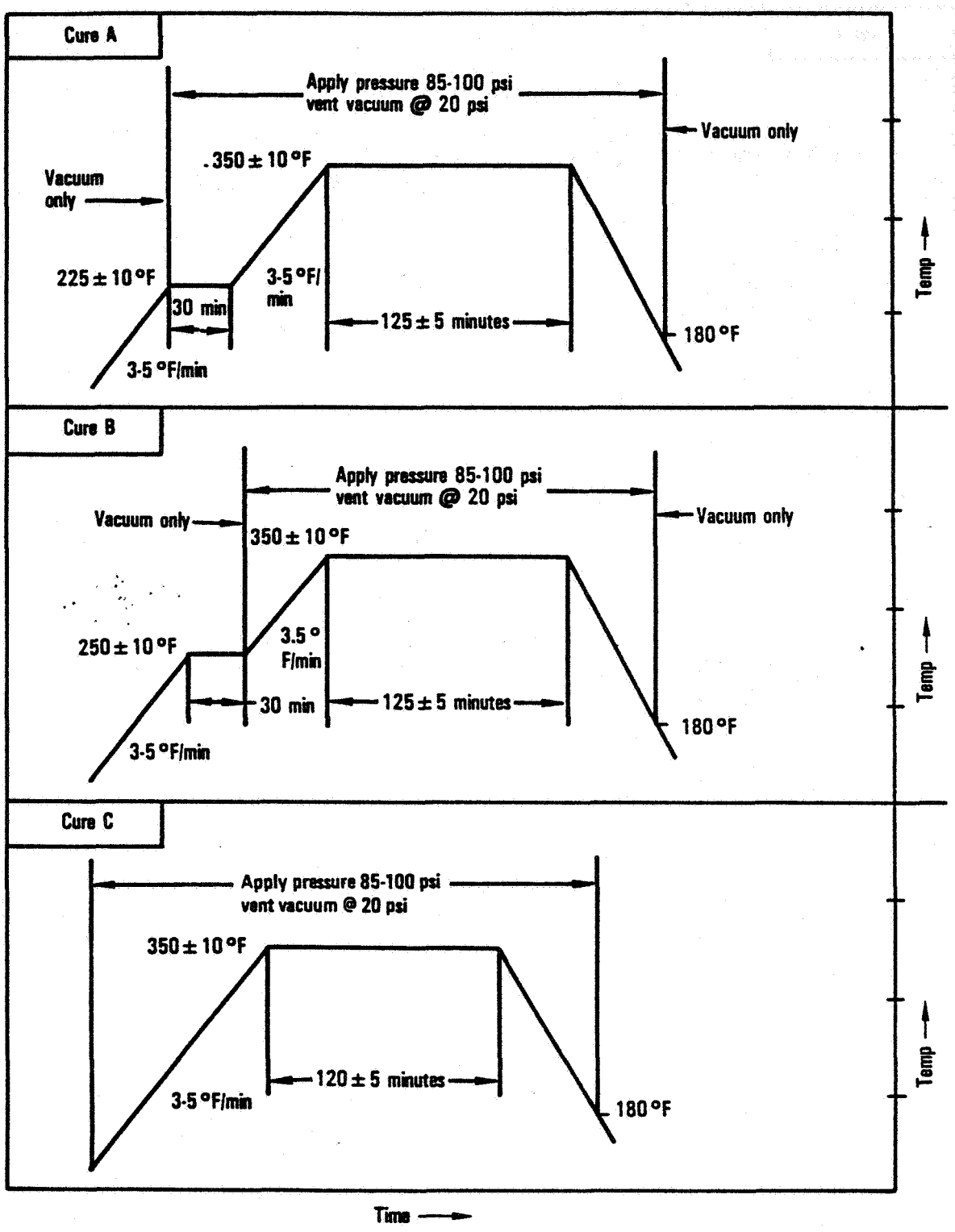
BATCH 2026

(1) ±30°.
(2) ±35°.
(3) 250°F Dwell.
(4) 260°F Dwell.
(5) Not available.
(6) Calculated from cert. data.

ORIGINAL PAGE IS
OF POOR QUALITY

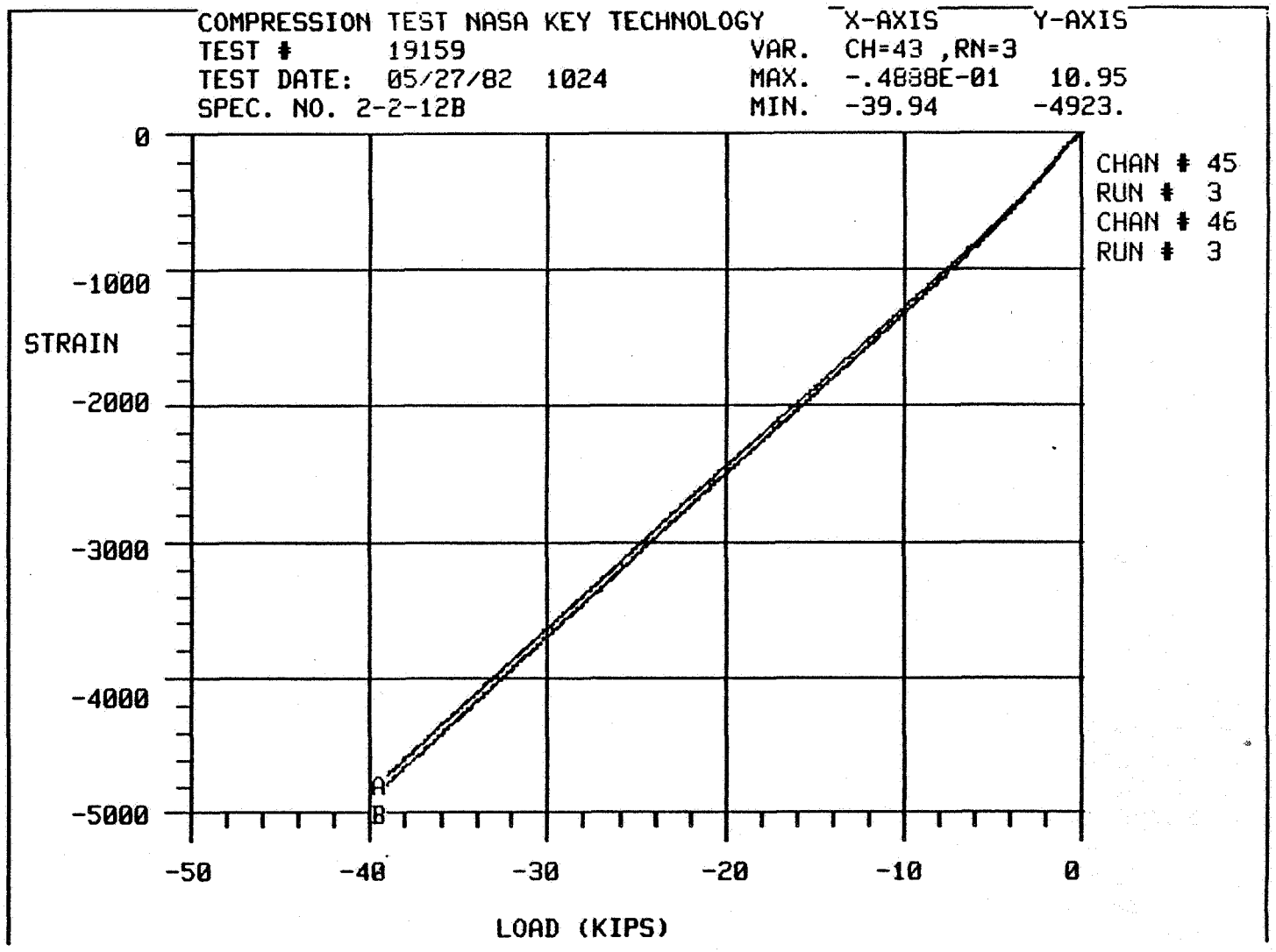


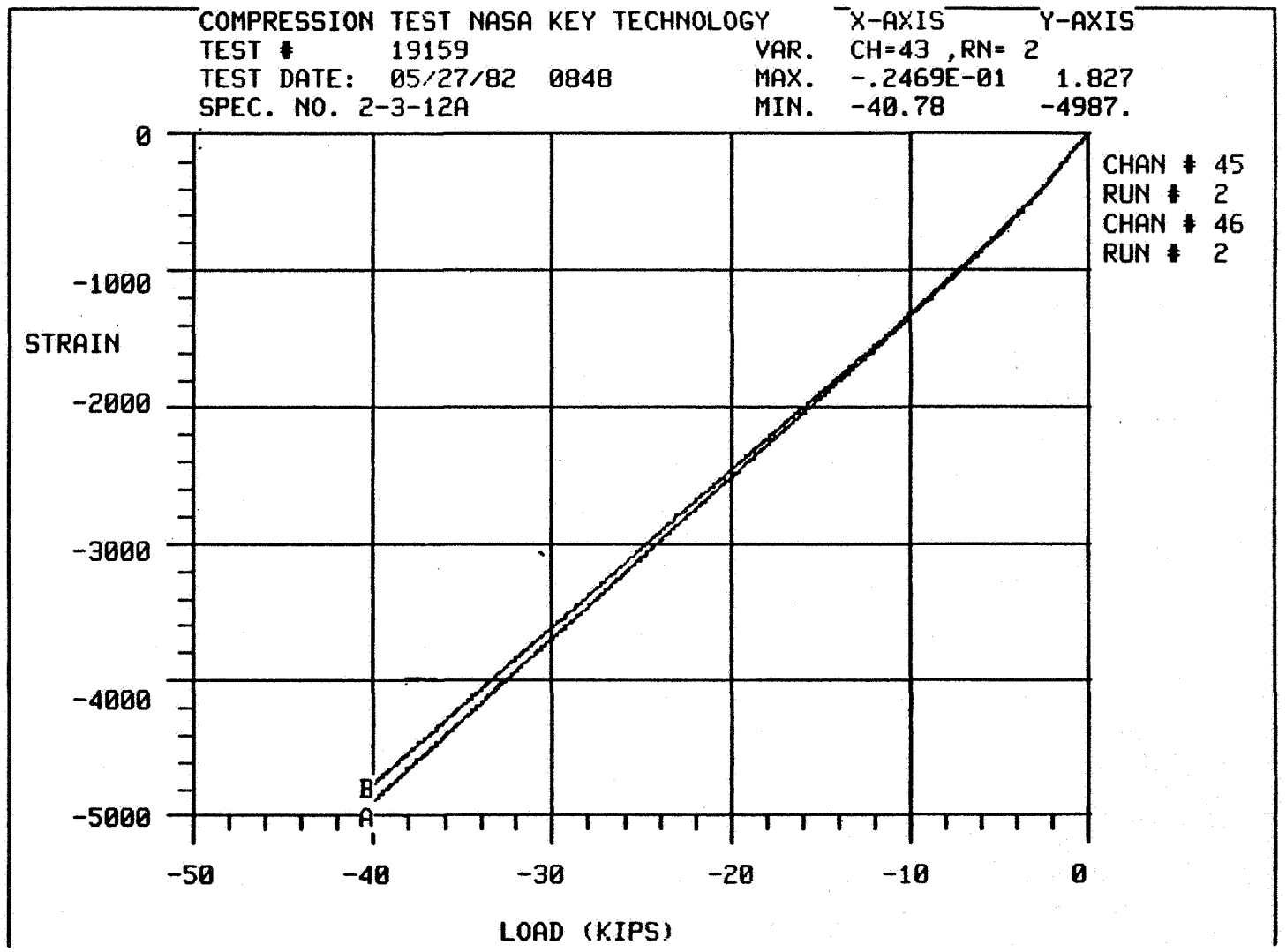
AS4/3502 - Autoclave cure cycles.

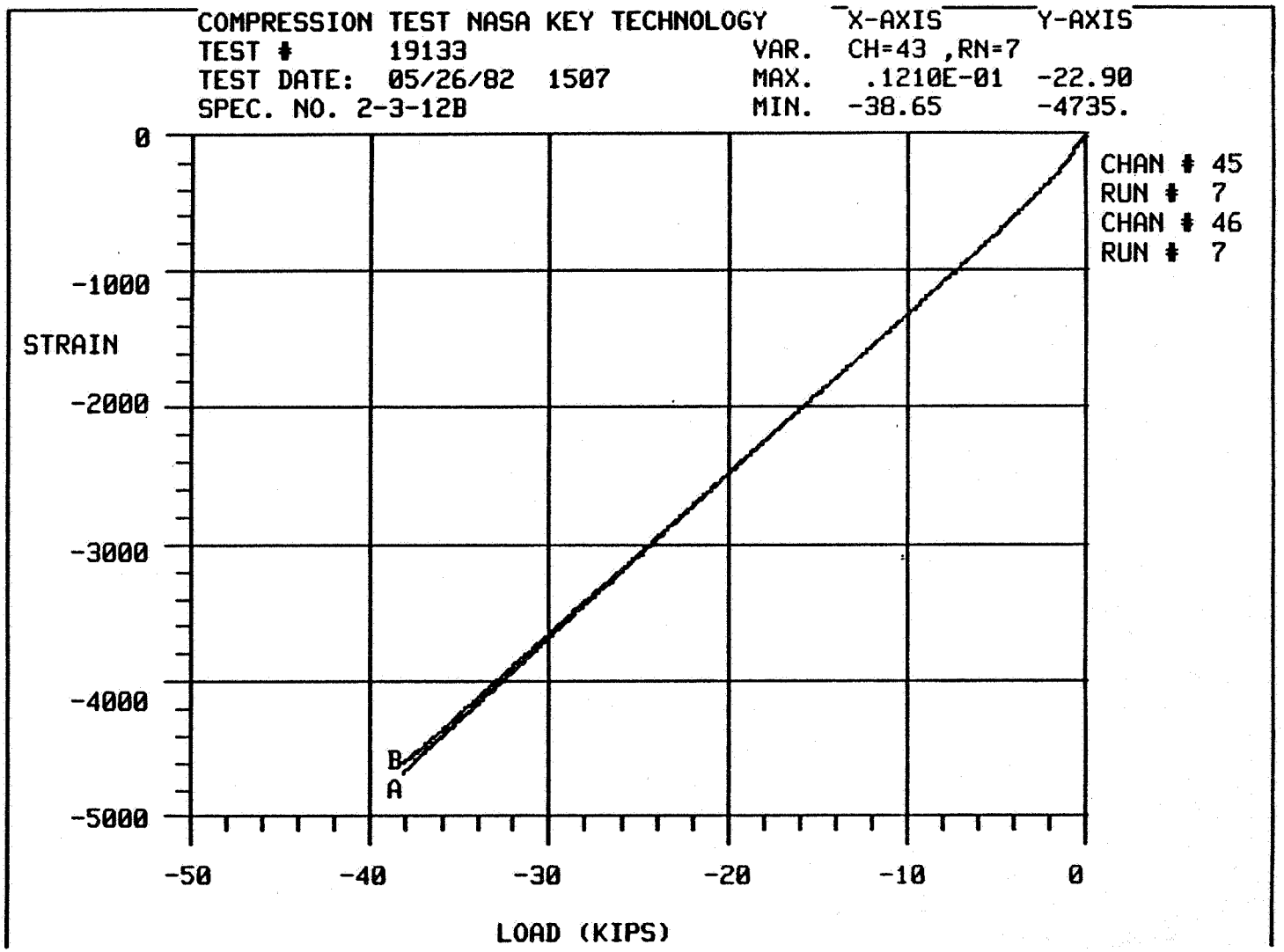


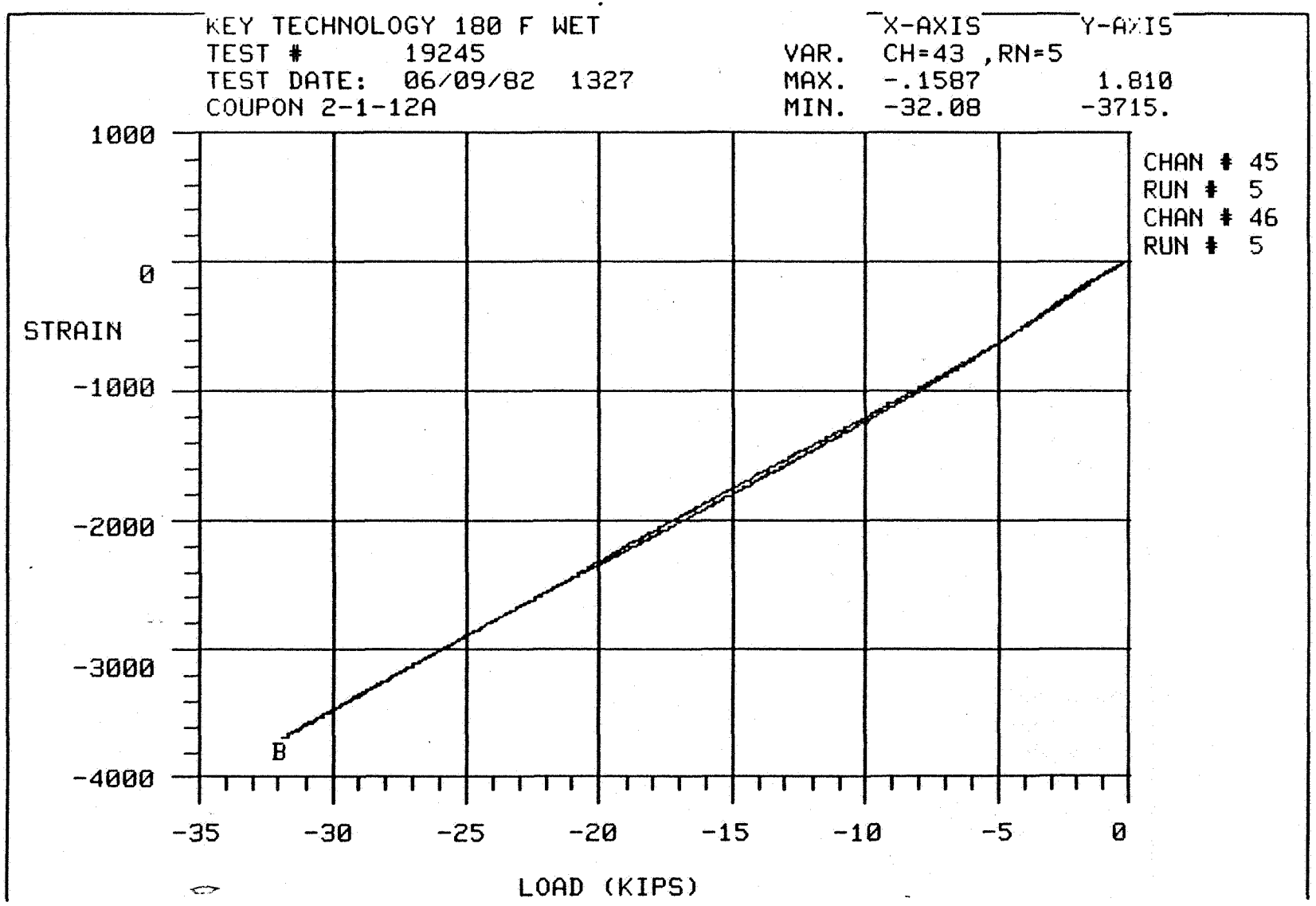
AS4/2220-1 - Autoclave cure cycles.

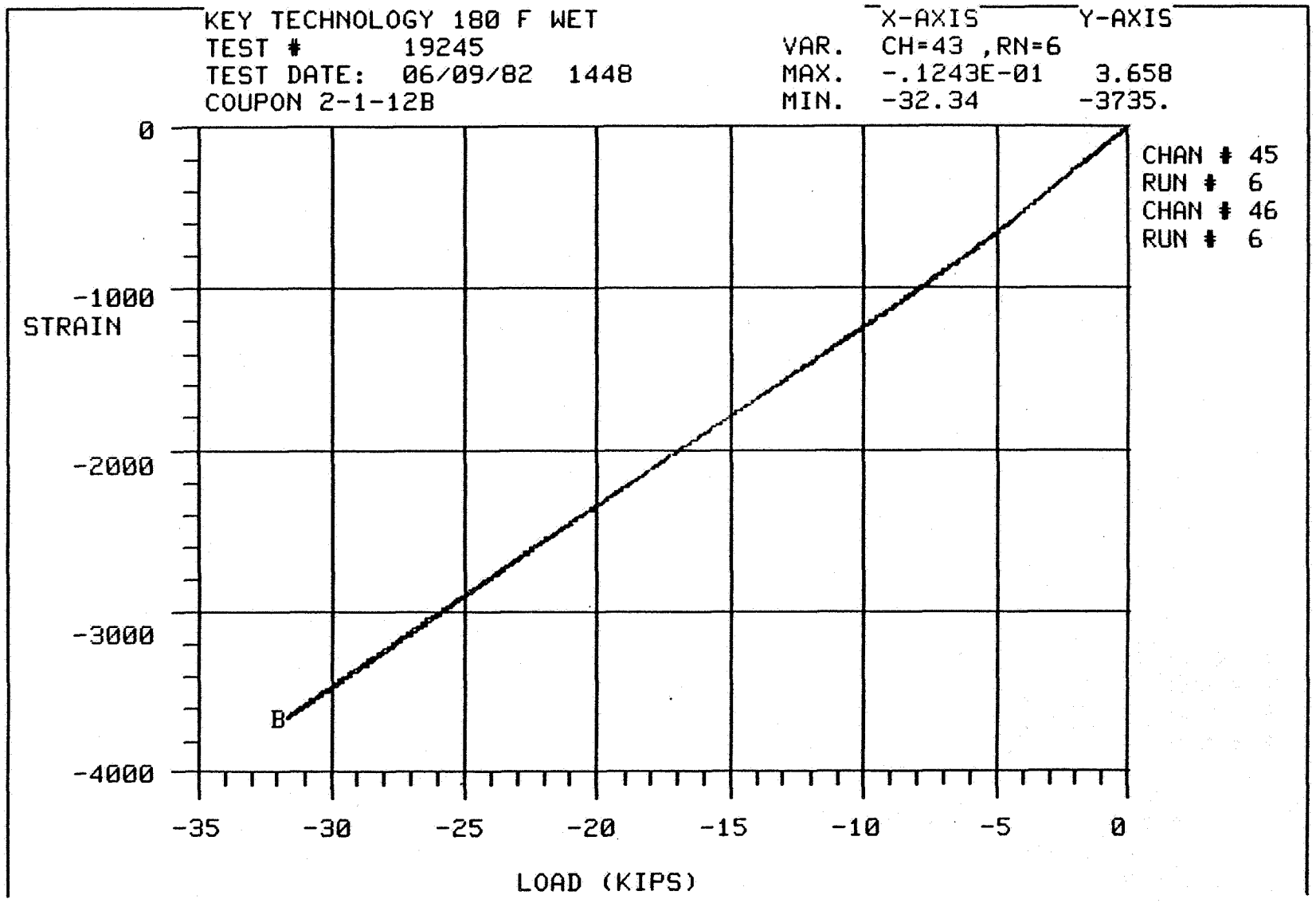
APPENDIX A-2

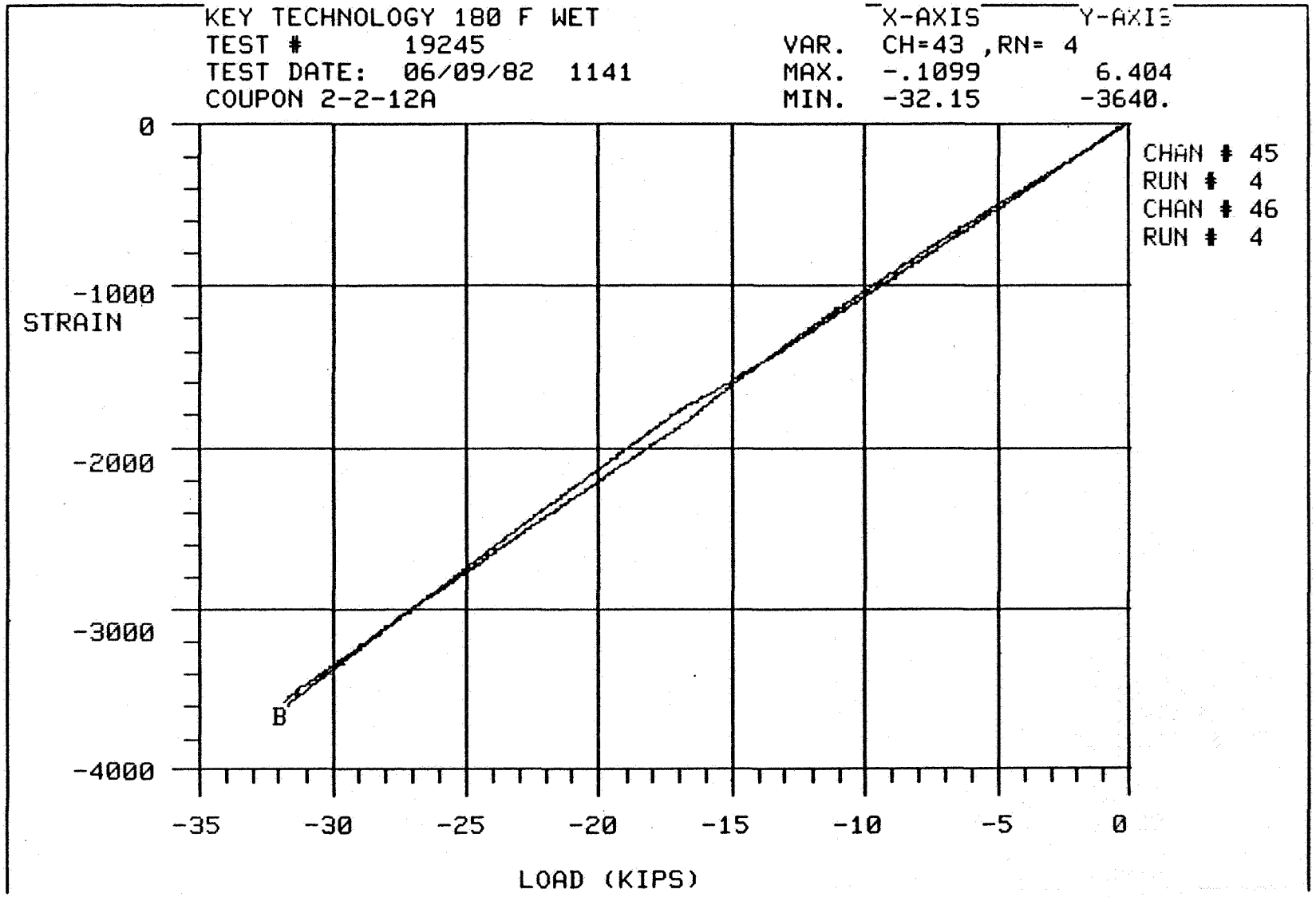

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19159
TEST DATE: 05/27/82 1024
SPEC. NO. 2-2-12B
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=3
MAX. -.4838E-01 10.95
MIN. -39.94 -4923.
CHAN # 45
RUN # 3
CHAN # 46
RUN # 3
0
-1000
-2000
-3000
-4000
-5000
STRAIN
-50
-40
-30
-20
-10
0
LOAD (KIPS)
A
B

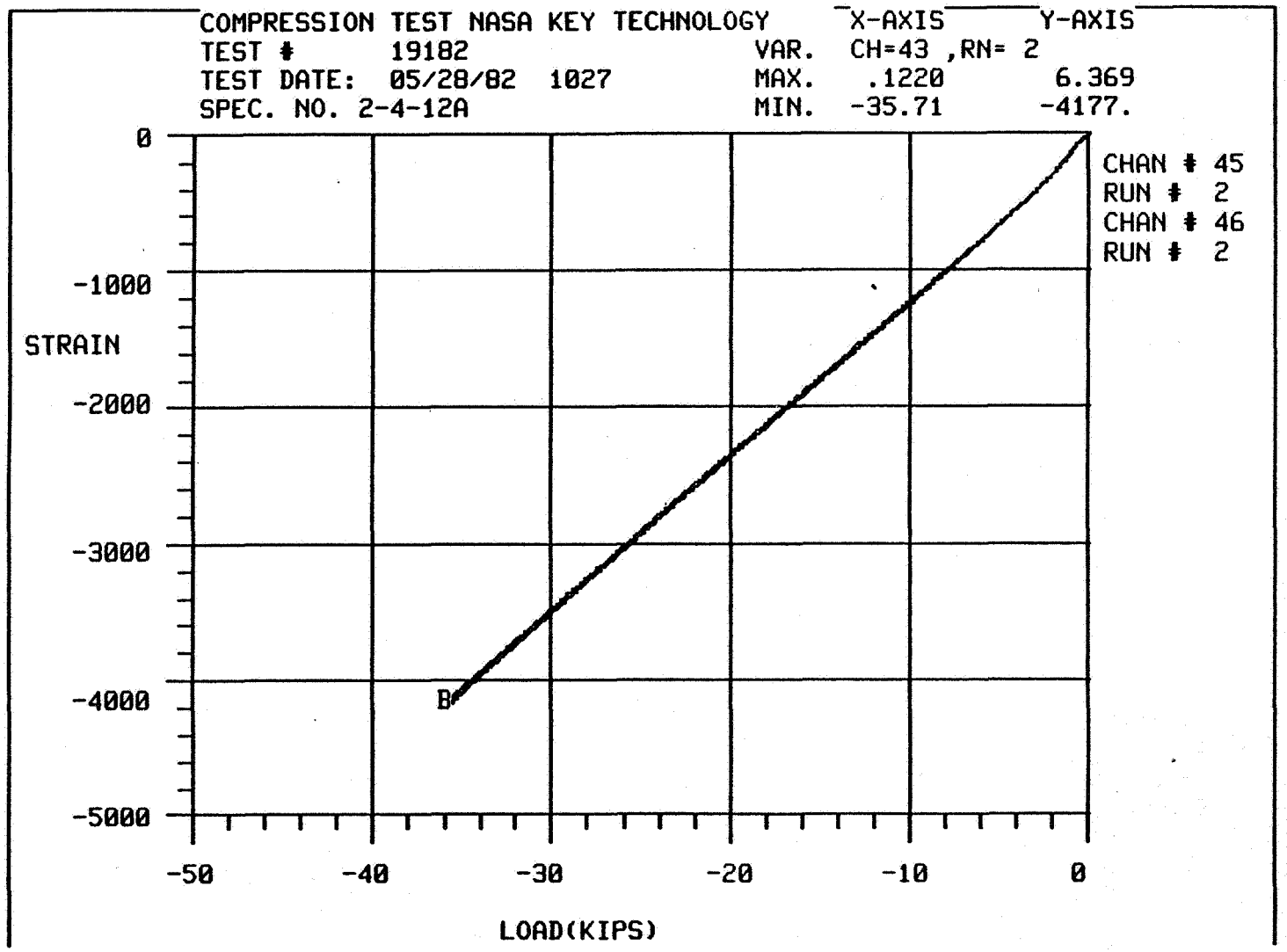

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19159
TEST DATE: 05/27/82 0848
SPEC. NO. 2-3-12A
X-AXIS
Y-AXIS
VAR. CH=43 ,RN= 2
MAX. -.2469E-01 1.827
MIN. -40.78 -4987.
CHAN # 45
RUN # 2
CHAN # 46
RUN # 2
0
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-2000
-3000
-4000
-5000
STRAIN
B
A
-50
-40
-30
-20
-10
0
LOAD (KIPS)

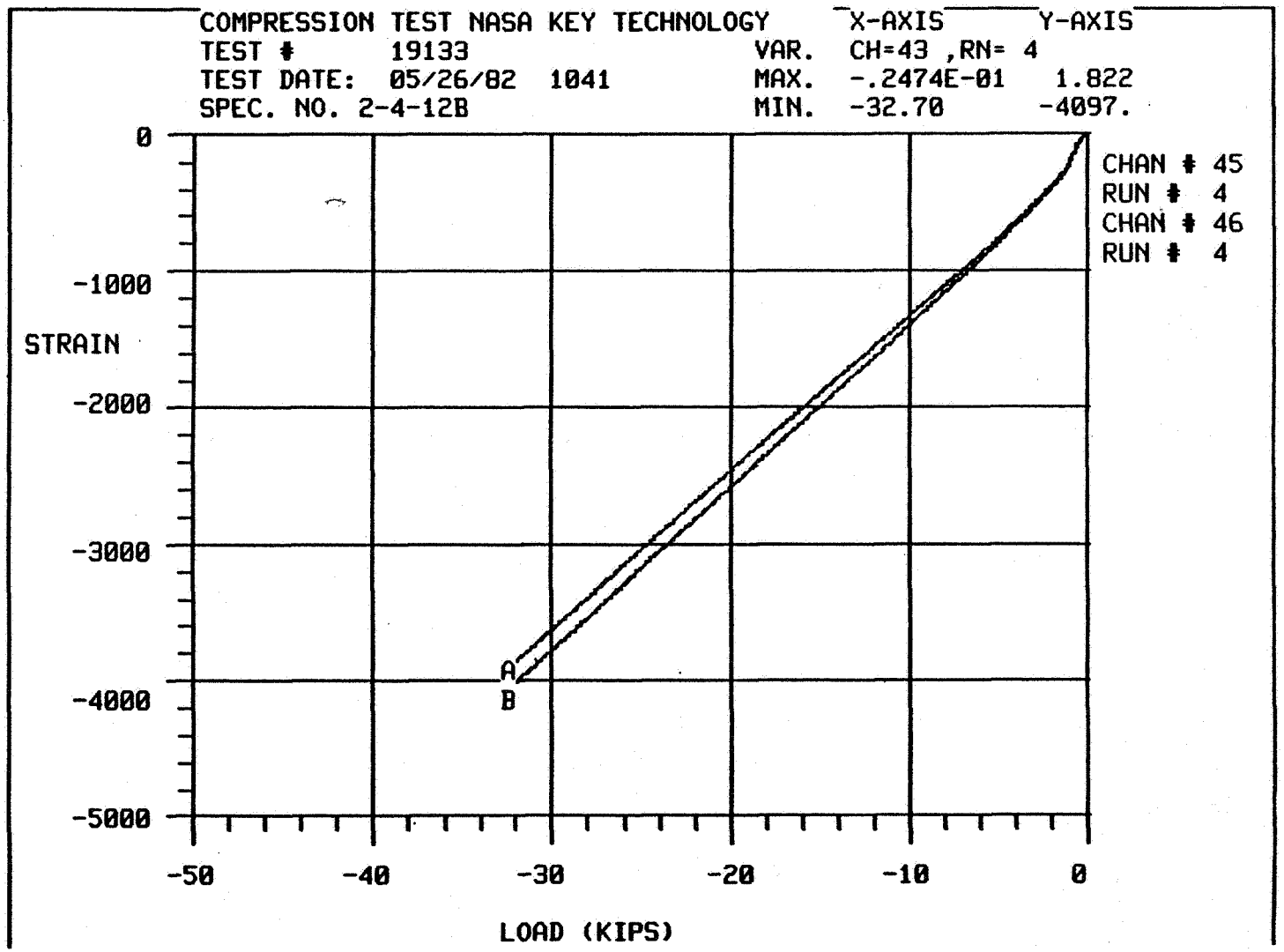

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19133
TEST DATE: 05/26/82 1507
SPEC. NO. 2-3-12B
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=7
MAX. .1210E-01 -22.90
MIN. -38.65 -4735.
CHAN # 45
RUN # 7
CHAN # 46
RUN # 7
0
-1000
-2000
-3000
-4000
-5000
STRAIN
-50
-40
-30
-20
-10
0
LOAD (KIPS)
B
A

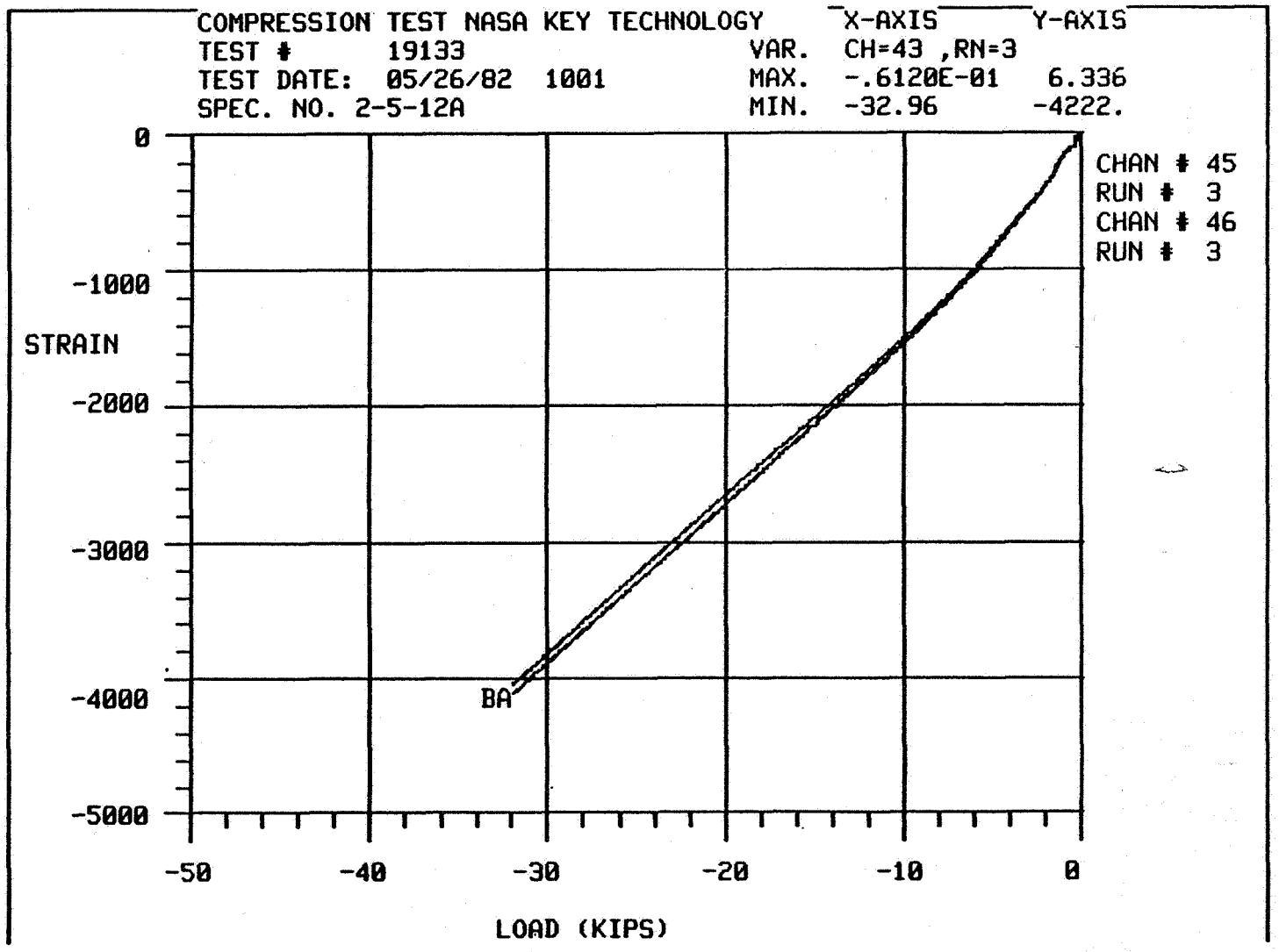

KEY TECHNOLOGY 180 F WET
TEST # 19245
TEST DATE: 06/09/82 1327
COUPON 2-1-12A
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=5
MAX. -.1587 1.810
MIN. -32.08 -3715.
CHAN # 45
RUN # 5
CHAN # 46
RUN # 5
1000
0
-1000
-2000
-3000
-4000
STRAIN
B
-35
-30
-25
-20
-15
-10
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0
LOAD (KIPS)

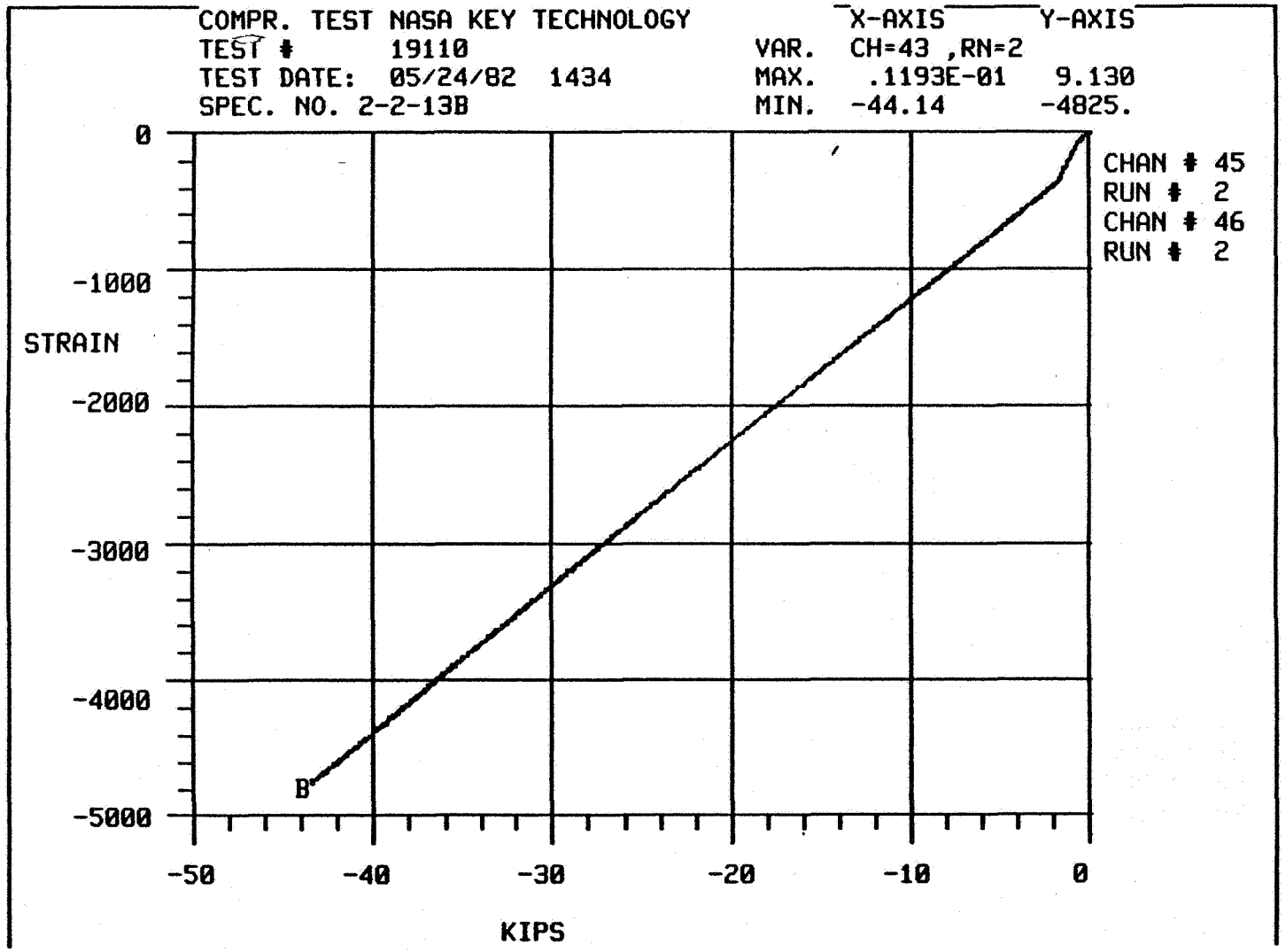

KEY TECHNOLOGY 180 F WET
TEST # 19245
TEST DATE: 06/09/82 1448
COUPON 2-1-12B
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=6
MAX. -.1243E-01 3.658
MIN. -32.34 -3735.
CHAN # 45
RUN # 6
CHAN # 46
RUN # 6
0
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STRAIN
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-4000
B
-35
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-20
-15
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LOAD (KIPS)

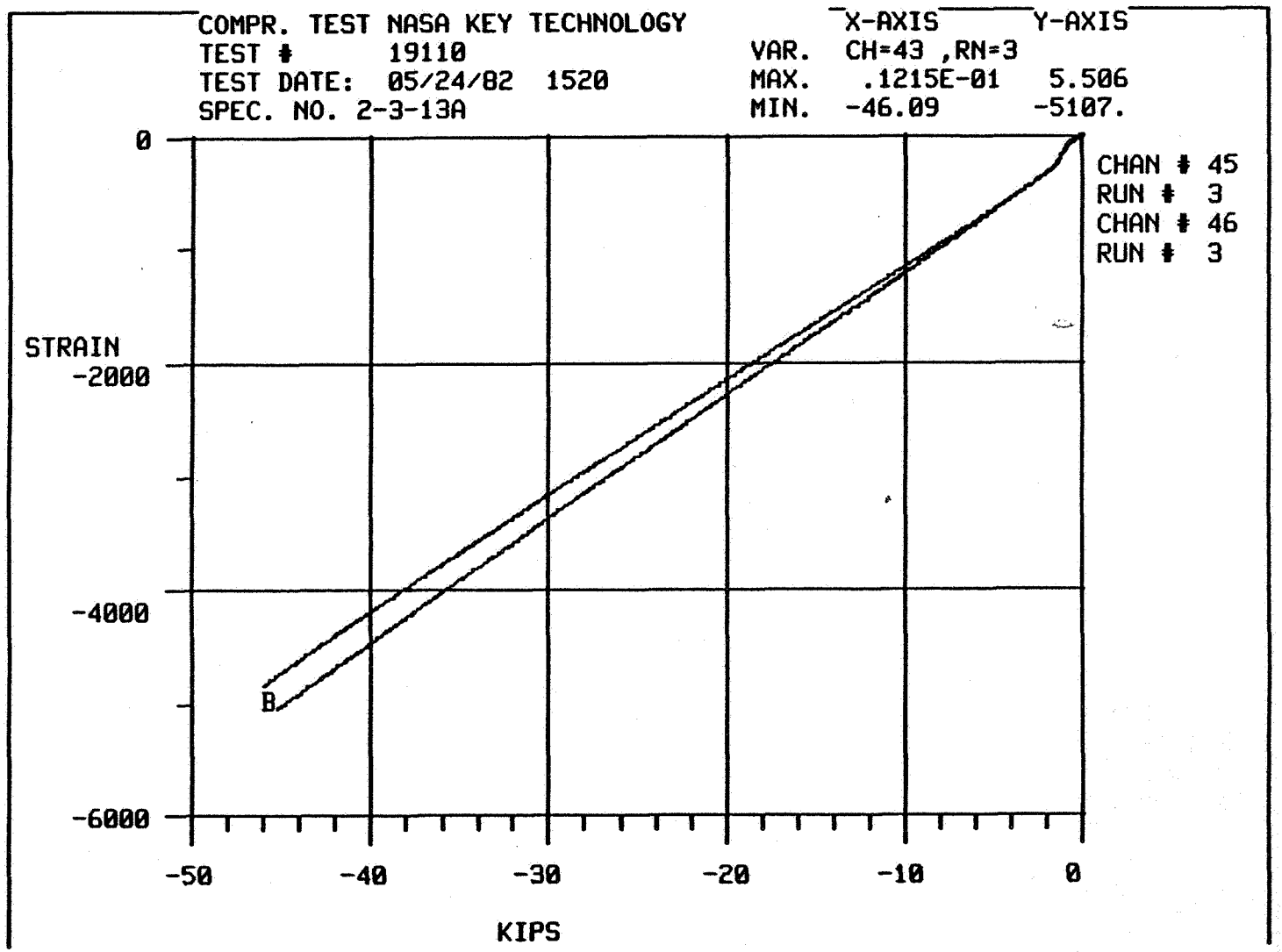

KEY TECHNOLOGY 180 F WET
TEST # 19245
TEST DATE: 06/09/82 1141
COUPON 2-2-12A
X-AXIS Y-AXIS
VAR. CH=43 ,RN= 4
MAX. -.1099 6.404
MIN. -32.15 -3640.
CHAN # 45
RUN # 4
CHAN # 46
RUN # 4
0
-1000
-2000
-3000
-4000
STRAIN
B
-35
-30
-25
-20
-15
-10
-5
0
LOAD (KIPS)

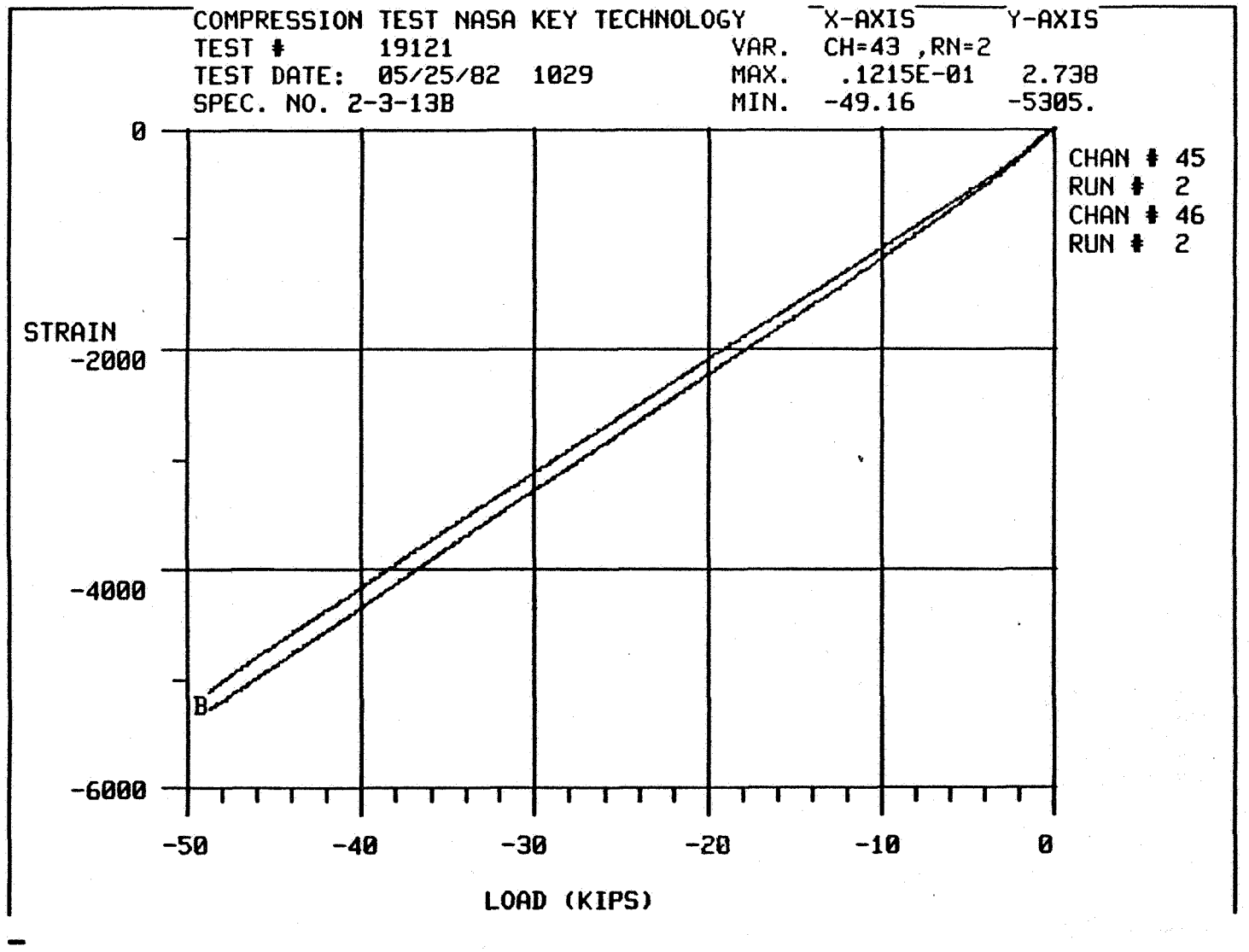

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19182
TEST DATE: 05/28/82 1027
SPEC. NO. 2-4-12A
X-AXIS
Y-AXIS
VAR. CH=43 ,RN= 2
MAX. .1220 6.369
MIN. -35.71 -4177.
CHAN # 45
RUN # 2
CHAN # 46
RUN # 2
0
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-4000
-5000
STRAIN
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-40
-30
-20
-10
0
LOAD(KIPS)
B

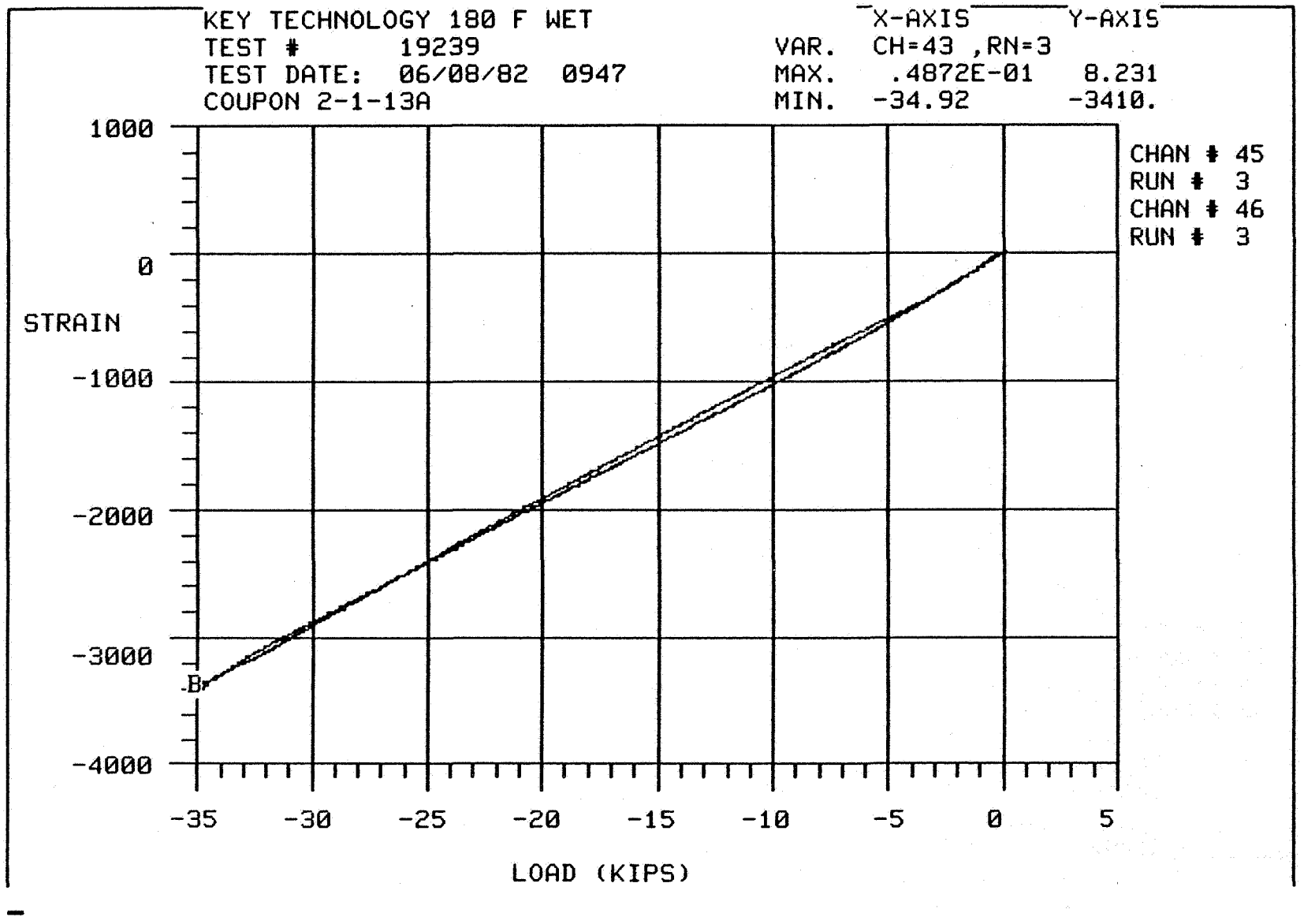

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19133
TEST DATE: 05/26/82 1041
SPEC. NO. 2-4-12B
X-AXIS Y-AXIS
VAR. CH=43 ,RN= 4
MAX. -.2474E-01 1.822
MIN. -32.70 -4097.
CHAN # 45
RUN # 4
CHAN # 46
RUN # 4
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-1000
-2000
-3000
-4000
-5000
STRAIN
A
B
-50
-40
-30
-20
-10
0
LOAD (KIPS)

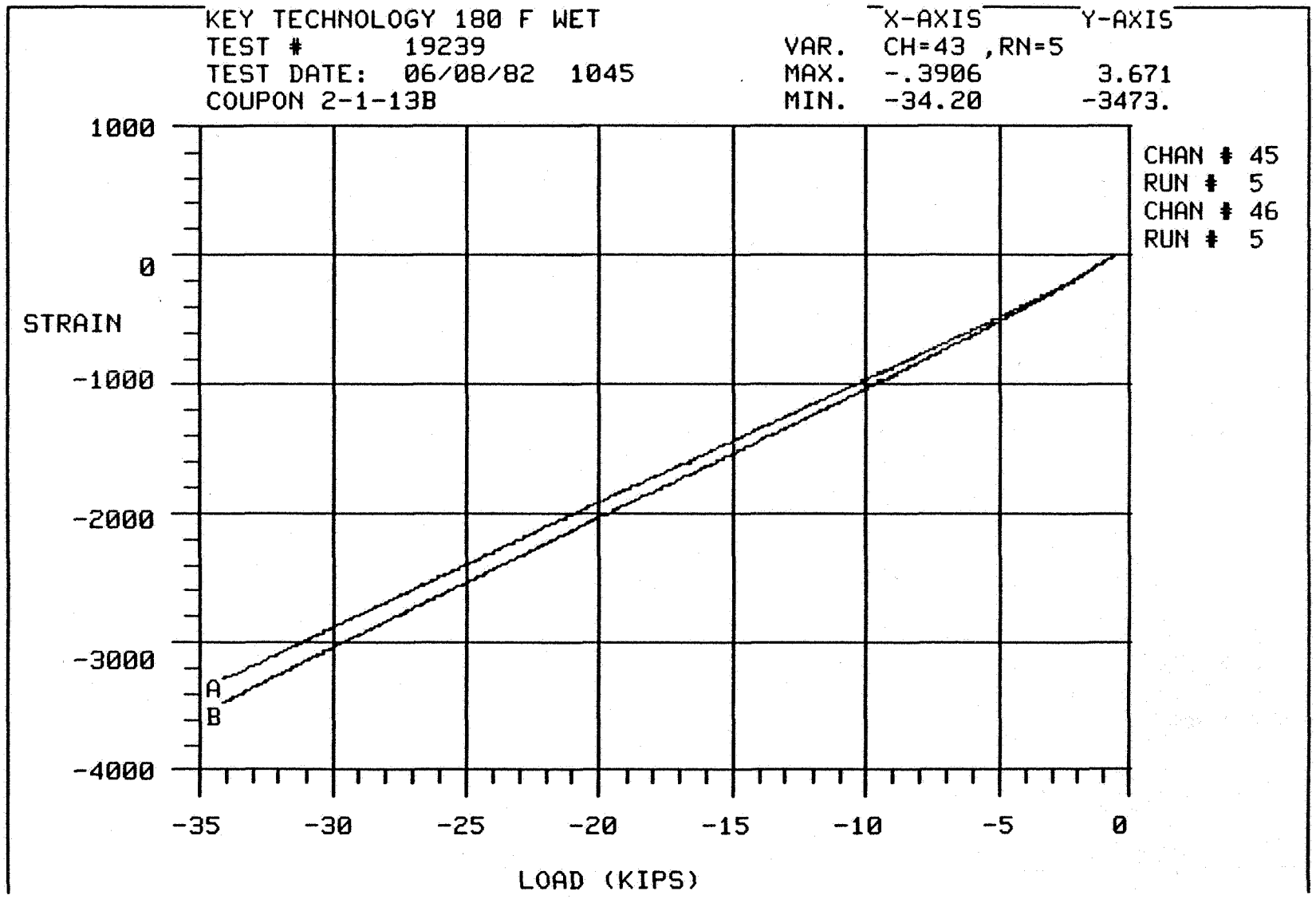

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19133
TEST DATE: 05/26/82 1001
SPEC. NO. 2-5-12A
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=3
MAX. -.6120E-01 6.336
MIN. -32.96 -4222.
CHAN # 45
RUN # 3
CHAN # 46
RUN # 3
0
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-2000
-3000
-4000
-5000
STRAIN
BA
-50
-40
-30
-20
-10
0
LOAD (KIPS)

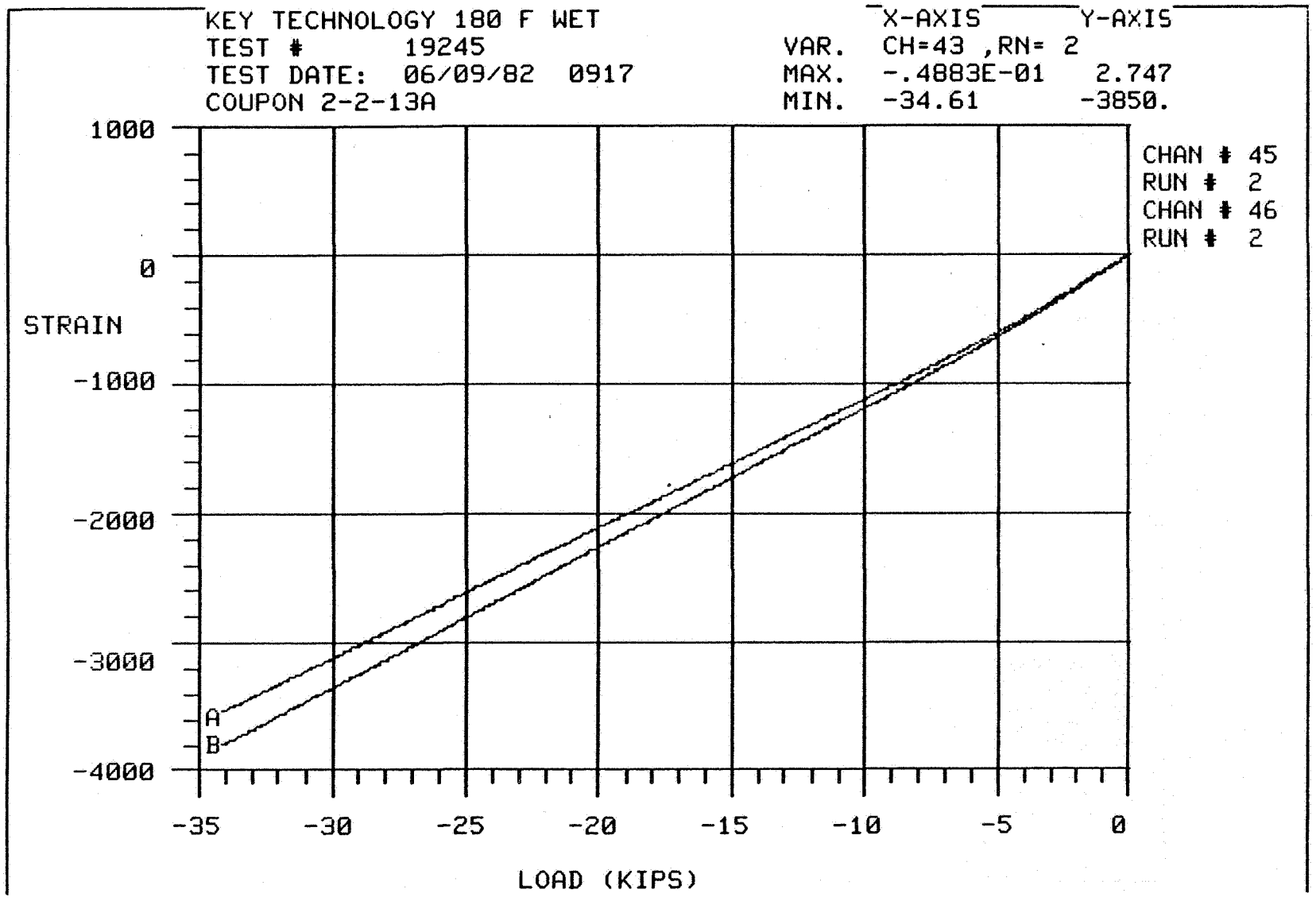

COMPR. TEST NASA KEY TECHNOLOGY
TEST # 19110
TEST DATE: 05/24/82 1434
SPEC. NO. 2-2-13B
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=2
MAX. .1193E-01 9.130
MIN. -44.14 -4825.
CHAN # 45
RUN # 2
CHAN # 46
RUN # 2
0
-1000
-2000
-3000
-4000
-5000
STRAIN
-50
-40
-30
-20
-10
0
KIPS
B

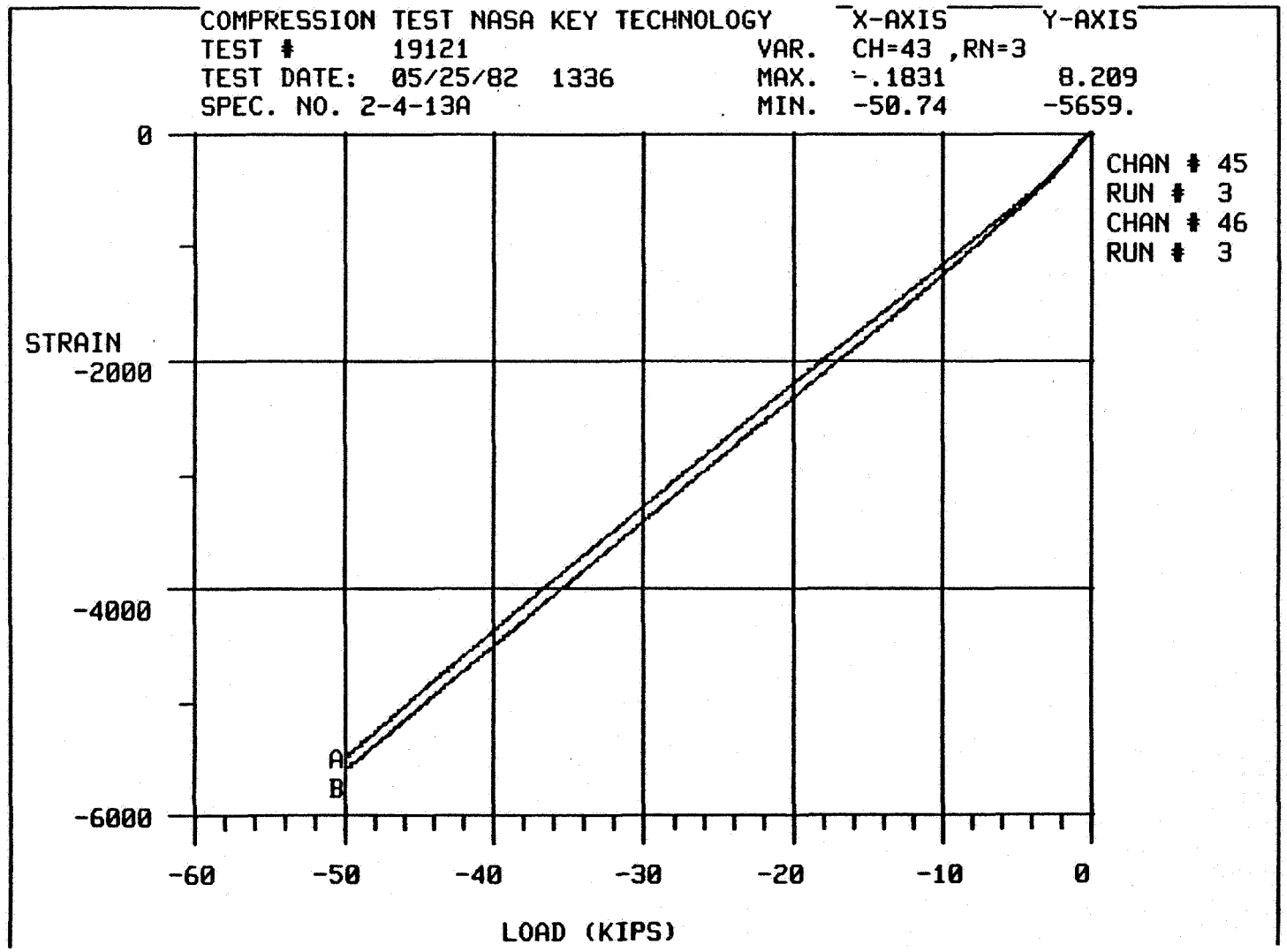

COMPR. TEST NASA KEY TECHNOLOGY
TEST # 19110
TEST DATE: 05/24/82 1520
SPEC. NO. 2-3-13A
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=3
MAX. .1215E-01 5.506
MIN. -46.09 -5107.
CHAN # 45
RUN # 3
CHAN # 46
RUN # 3
STRAIN
0
-2000
-4000
-6000
-50
-40
-30
-20
-10
0
KIPS
B

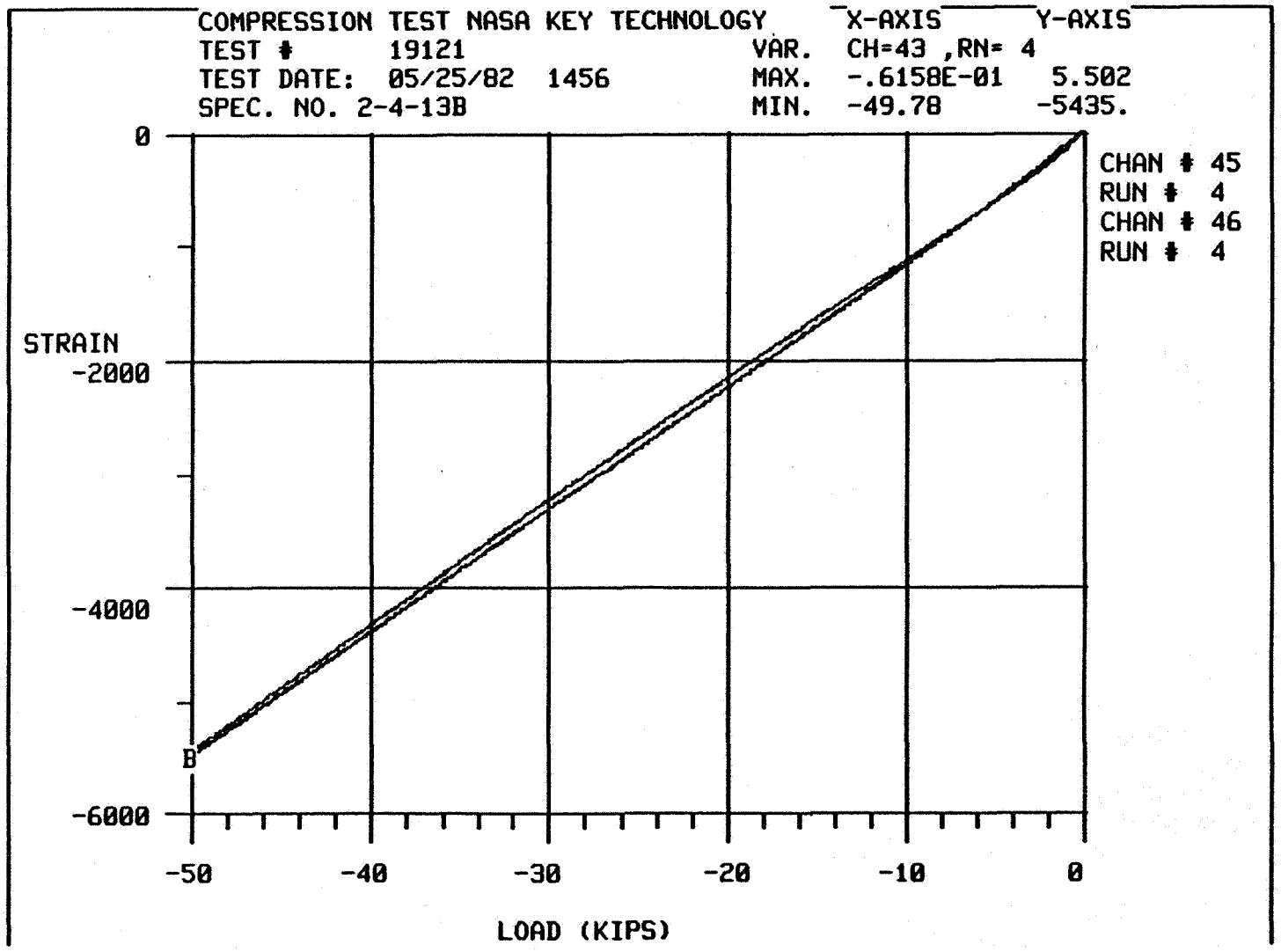

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19121
TEST DATE: 05/25/82 1029
SPEC. NO. 2-3-13B
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=2
MAX. .1215E-01 2.738
MIN. -49.16 -5305.
CHAN # 45
RUN # 2
CHAN # 46
RUN # 2
STRAIN
0
-2000
-4000
-6000
-50
-40
-30
-20
-10
0
LOAD (KIPS)
B

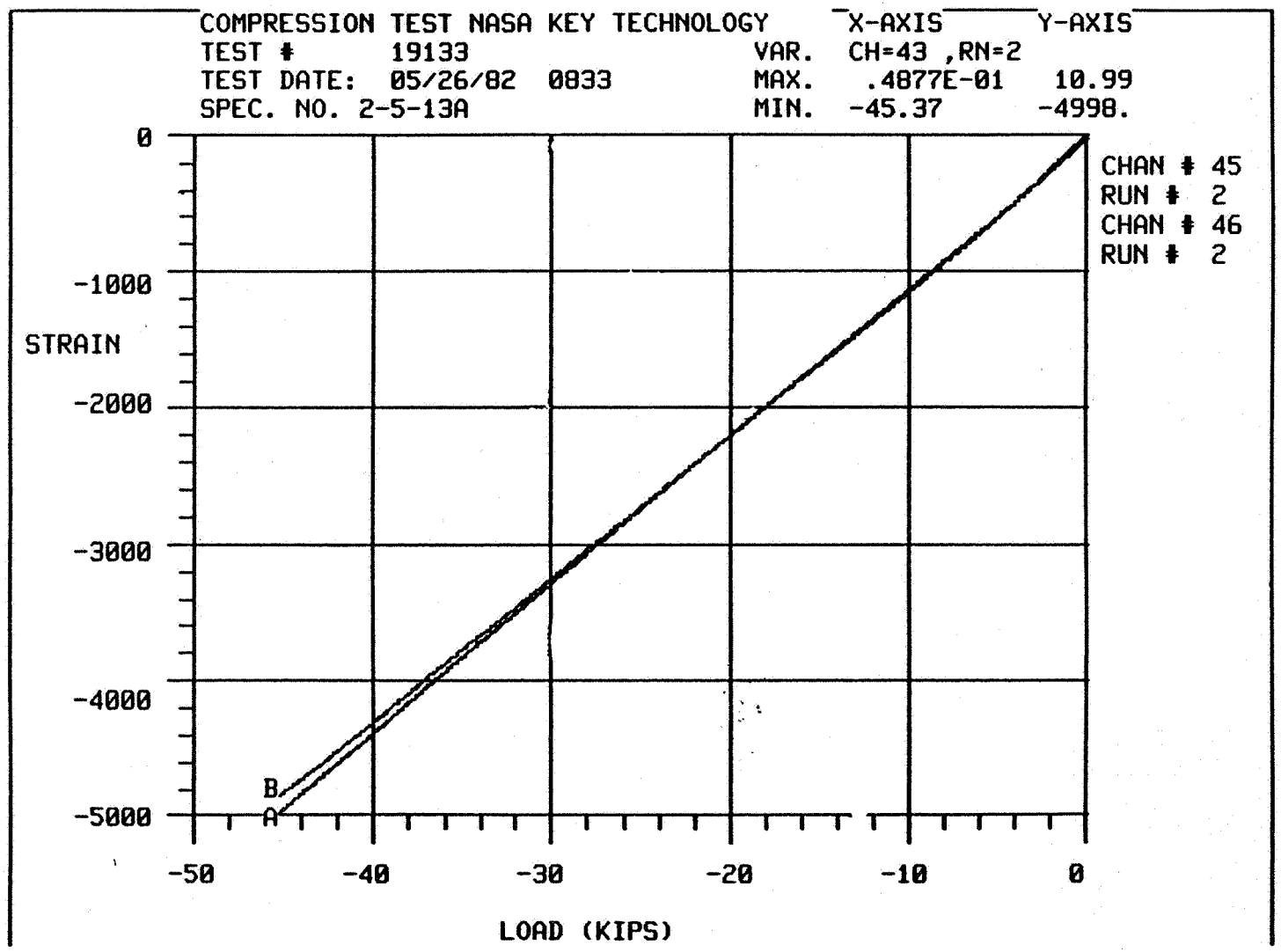

KEY TECHNOLOGY 180 F WET
TEST # 19239
TEST DATE: 06/08/82 0947
COUPON 2-1-13A
X-AXIS Y-AXIS
VAR. CH=43 ,RN=3
MAX. .4872E-01 8.231
MIN. -34.92 -3410.
CHAN # 45
RUN # 3
CHAN # 46
RUN # 3
1000
0
-1000
-2000
-3000
-4000
STRAIN
B
-35
-30
-25
-20
-15
-10
-5
0
5
LOAD (KIPS)

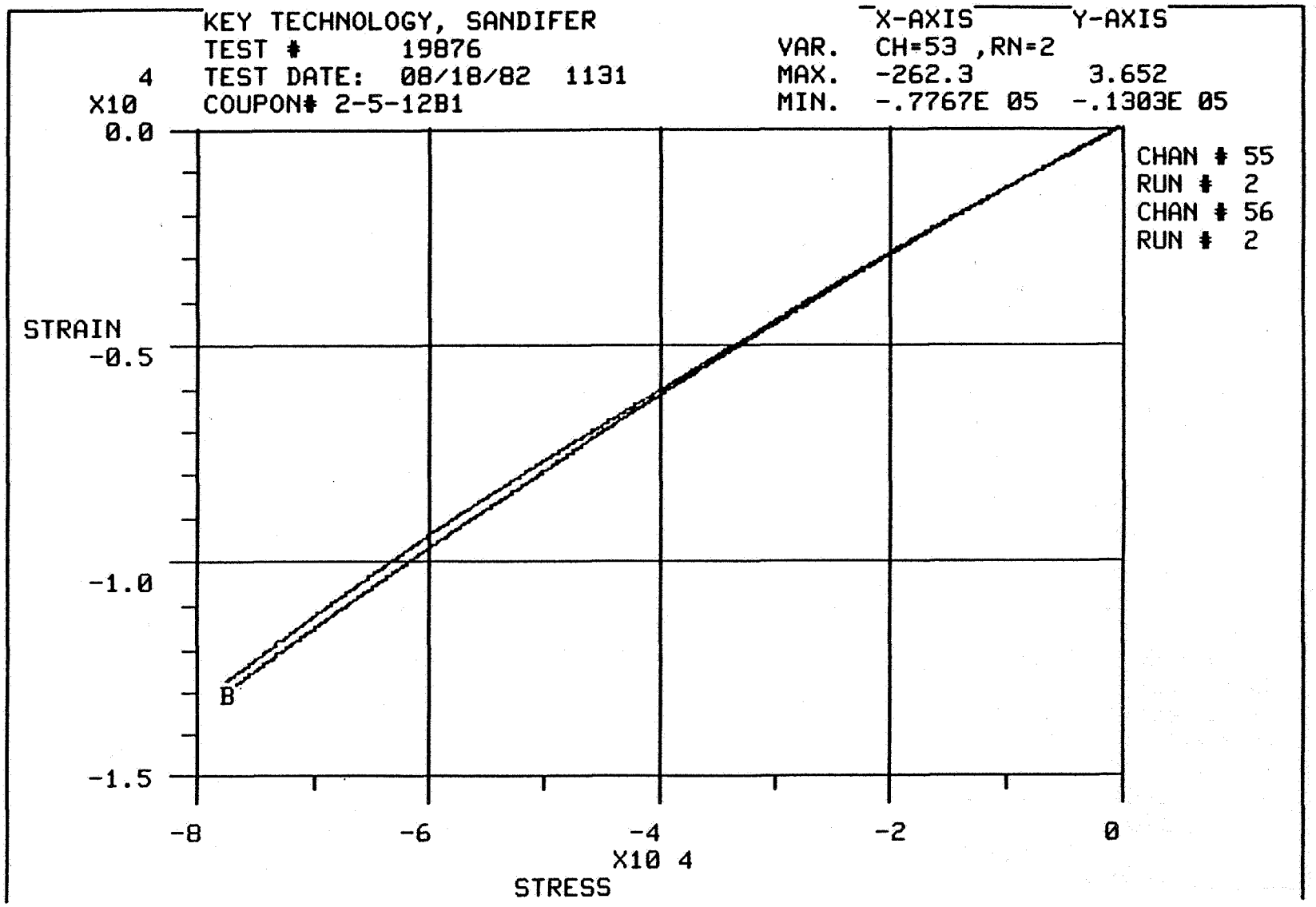

KEY TECHNOLOGY 180 F WET
TEST # 19239
TEST DATE: 06/08/82 1045
COUPON 2-1-13B
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=5
MAX. -.3906 3.671
MIN. -34.20 -3473.
CHAN # 45
RUN # 5
CHAN # 46
RUN # 5
1000
0
-1000
-2000
-3000
-4000
STRAIN
A
B
-35
-30
-25
-20
-15
-10
-5
0
LOAD (KIPS)

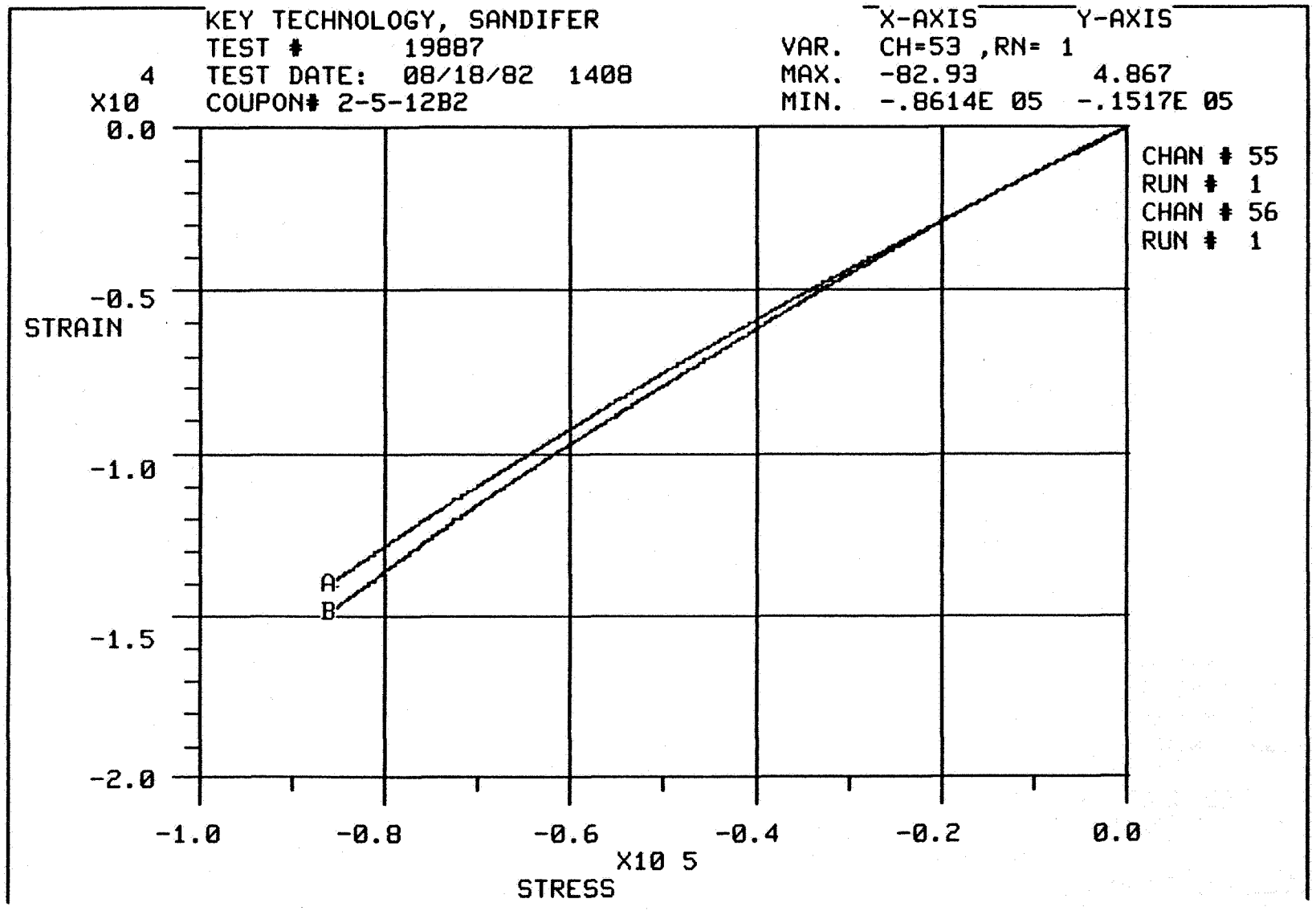

KEY TECHNOLOGY 180 F WET
TEST # 19245
TEST DATE: 06/09/82 0917
COUPON 2-2-13A
X-AXIS Y-AXIS
VAR. CH=43 ,RN= 2
MAX. -.4883E-01 2.747
MIN. -34.61 -3850.
CHAN # 45
RUN # 2
CHAN # 46
RUN # 2
1000
0
-1000
-2000
-3000
-4000
STRAIN
A
B
-35
-30
-25
-20
-15
-10
-5
0
LOAD (KIPS)

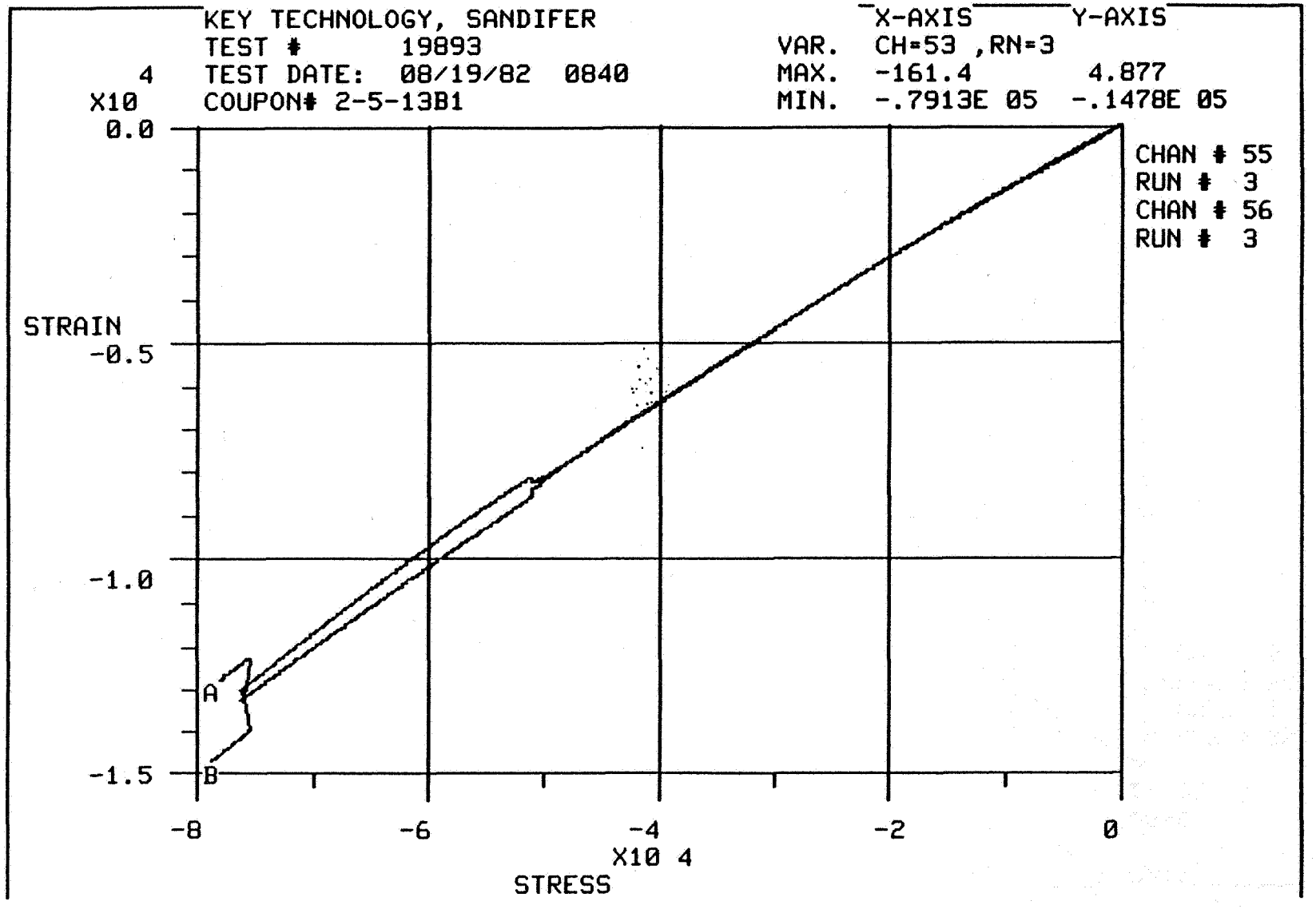

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19121
TEST DATE: 05/25/82 1336
SPEC. NO. 2-4-13A
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=3
MAX. -.1831 8.209
MIN. -50.74 -5659.
CHAN # 45
RUN # 3
CHAN # 46
RUN # 3
STRAIN
0
-2000
-4000
-6000
A
B
-60
-50
-40
-30
-20
-10
0
LOAD (KIPS)

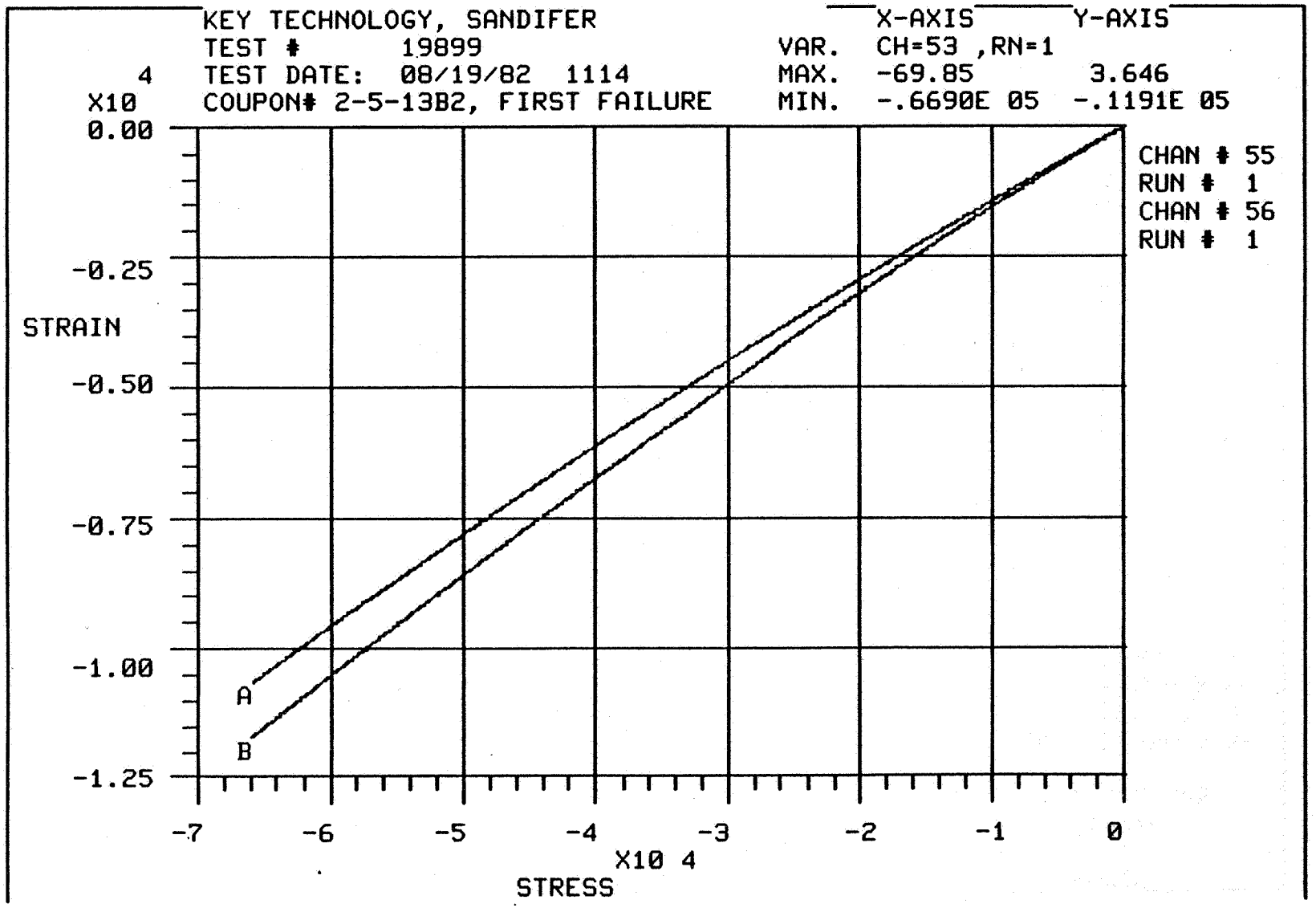

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19121
TEST DATE: 05/25/82 1456
SPEC. NO. 2-4-13B
X-AXIS
Y-AXIS
VAR. CH=43 ,RN= 4
MAX. -.6158E-01 5.502
MIN. -49.78 -5435.
CHAN # 45
RUN # 4
CHAN # 46
RUN # 4
STRAIN
0
-2000
-4000
-6000
B
-50
-40
-30
-20
-10
0
LOAD (KIPS)

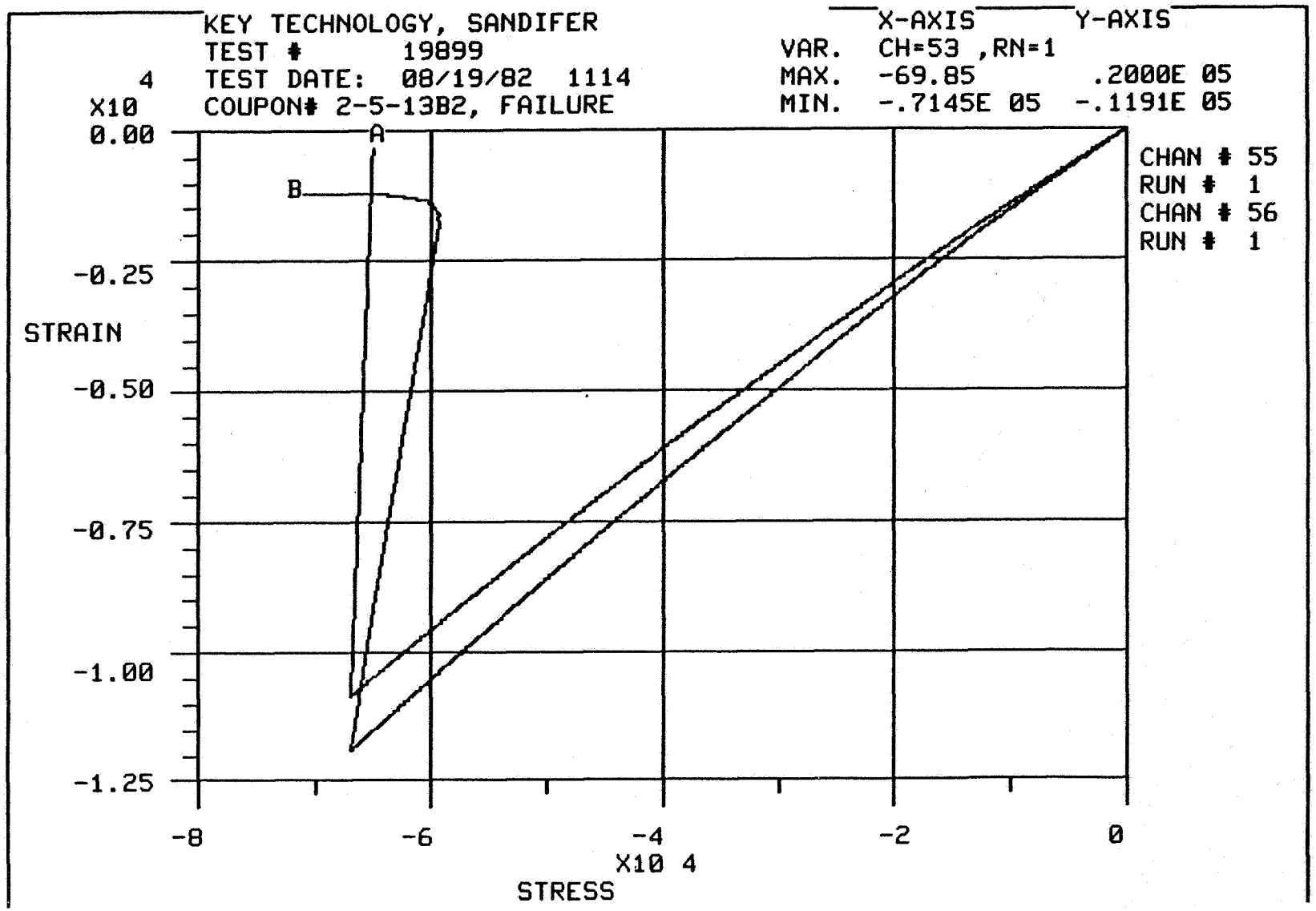

COMPRESSION TEST NASA KEY TECHNOLOGY
TEST # 19133
TEST DATE: 05/26/82 0833
SPEC. NO. 2-5-13A
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=2
MAX. .4877E-01 10.99
MIN. -45.37 -4998.
CHAN # 45
RUN # 2
CHAN # 46
RUN # 2
0
-1000
-2000
-3000
-4000
-5000
STRAIN
B
A
-50
-40
-30
-20
-10
0
LOAD (KIPS)


KEY TECHNOLOGY, SANDIFER
TEST # 19876
TEST DATE: 08/18/82 1131
COUPON# 2-5-12B1
X-AXIS Y-AXIS
VAR. CH=53 ,RN=2
MAX. -262.3 3.652
MIN. -.7767E 05 -.1303E 05
4
X10
0.0
-0.5
-1.0
-1.5
STRAIN
-8
-6
-4
-2
0
X10 4
STRESS
B
CHAN # 55
RUN # 2
CHAN # 56
RUN # 2

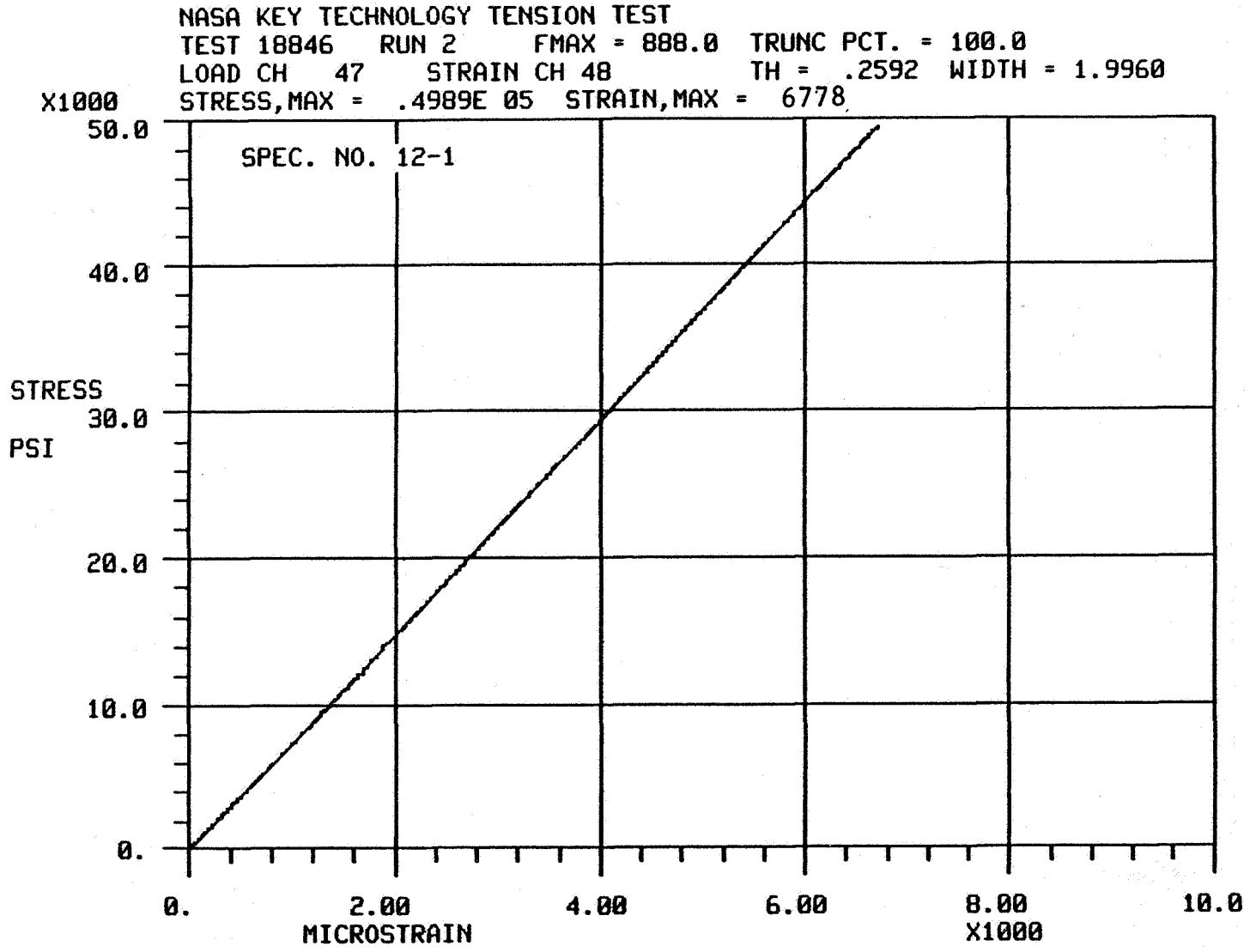

KEY TECHNOLOGY, SANDIFER
TEST # 19887
TEST DATE: 08/18/82 1408
COUPON# 2-5-12B2
X-AXIS Y-AXIS
VAR. CH=53 ,RN= 1
MAX. -82.93 4.867
MIN. -.8614E 05 -.1517E 05
4
X10
0.0
-0.5
-1.0
-1.5
-2.0
STRAIN
CHAN # 55
RUN # 1
CHAN # 56
RUN # 1
A
B
-1.0
-0.8
-0.6
-0.4
-0.2
0.0
X10 5
STRESS

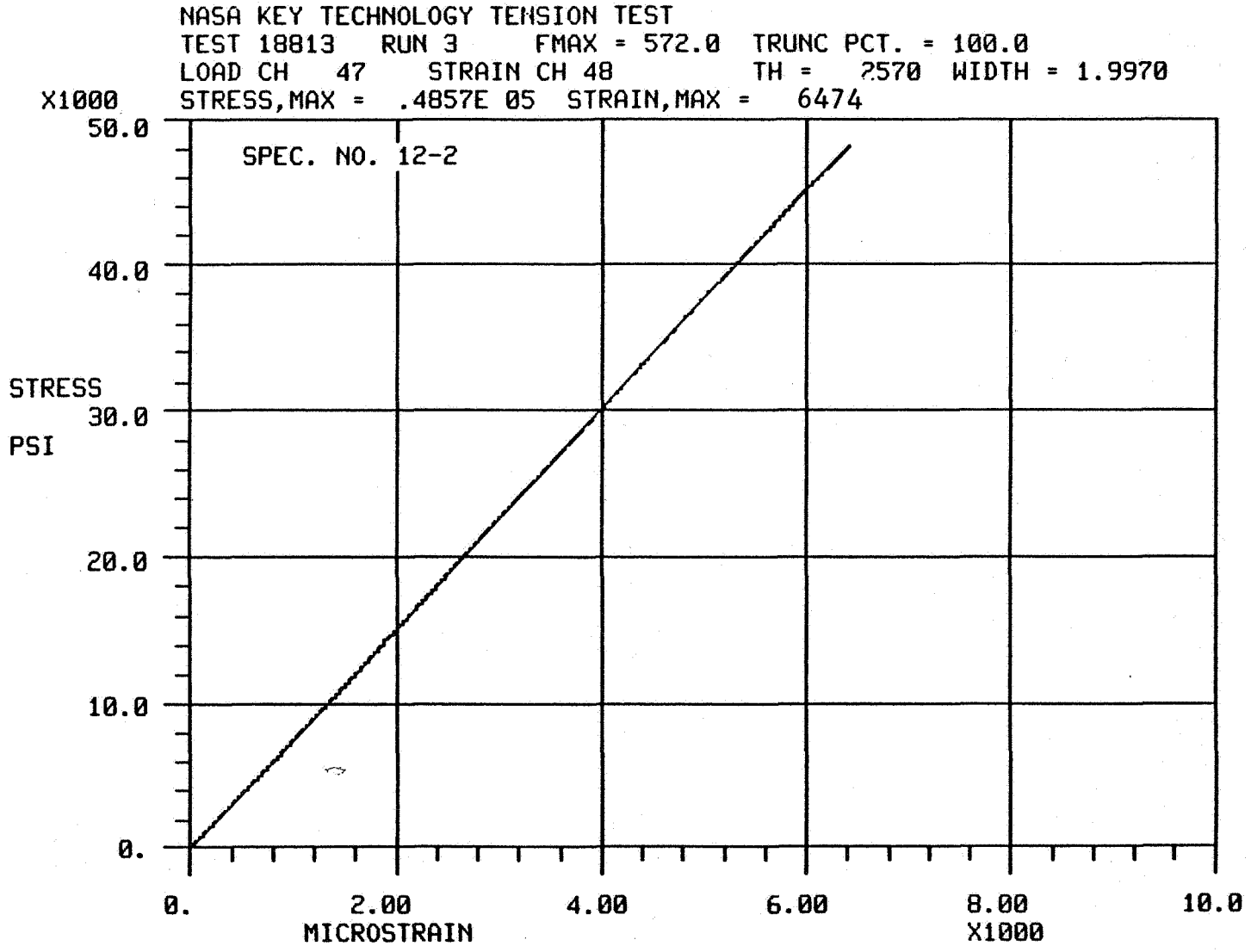

KEY TECHNOLOGY, SANDIFER
TEST # 19893
TEST DATE: 08/19/82 0840
COUPON# 2-5-13B1
X-AXIS
Y-AXIS
VAR. CH=53 ,RN=3
MAX. -161.4 4.877
MIN. -.7913E 05 -.1478E 05
4
X10
0.0
-0.5
-1.0
-1.5
STRAIN
CHAN # 55
RUN # 3
CHAN # 56
RUN # 3
A
B
-8
-6
-4
-2
0
X10 4
STRESS

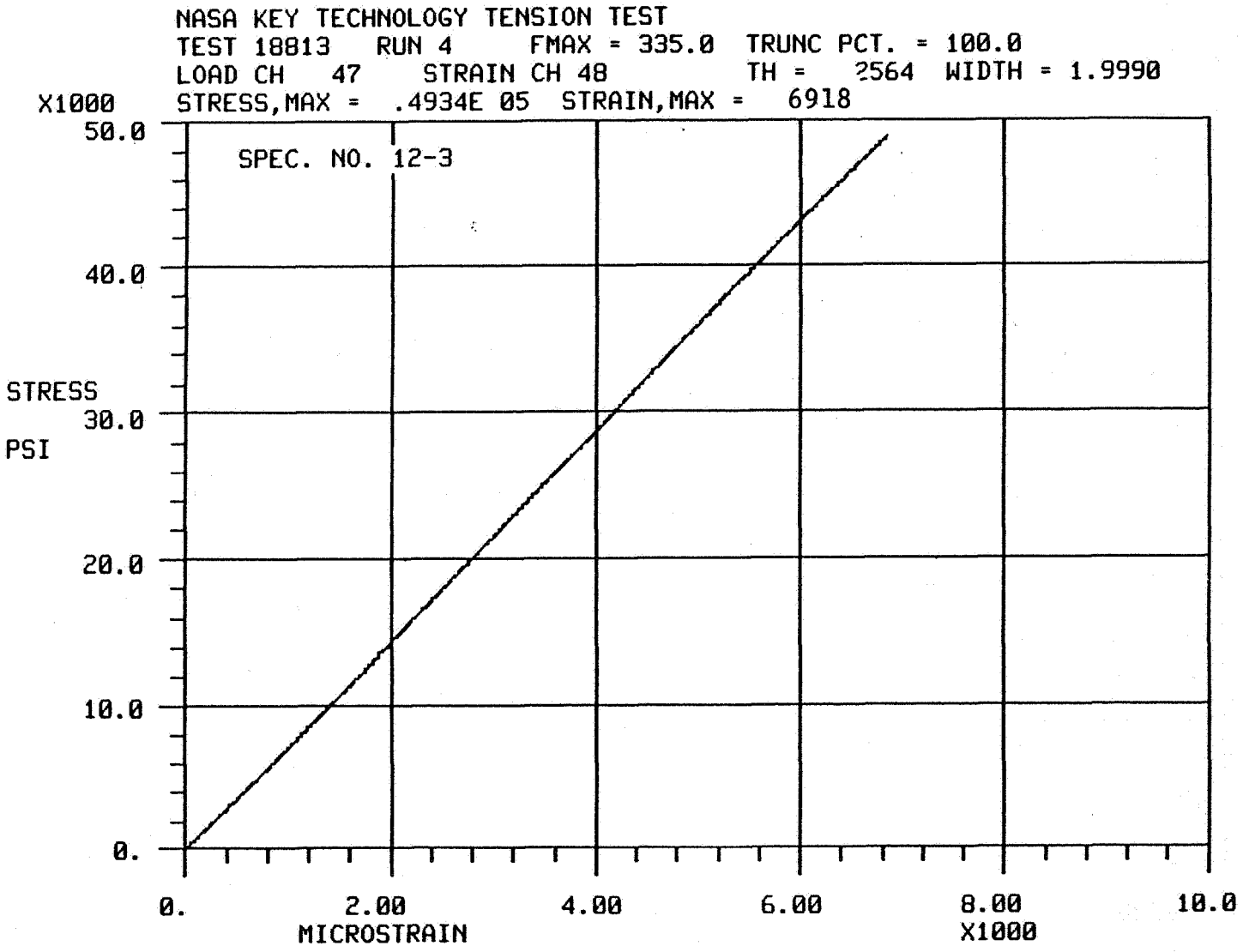

KEY TECHNOLOGY, SANDIFER
TEST # 19899
TEST DATE: 08/19/82 1114
COUPON# 2-5-13B2, FIRST FAILURE
X-AXIS Y-AXIS
VAR. CH=53 ,RN=1
MAX. -69.85 3.646
MIN. -.6690E 05 -.1191E 05
4
X10
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
STRAIN
-7 -6 -5 -4 -3 -2 -1 0
X10 4
STRESS
A
B
CHAN # 55
RUN # 1
CHAN # 56
RUN # 1

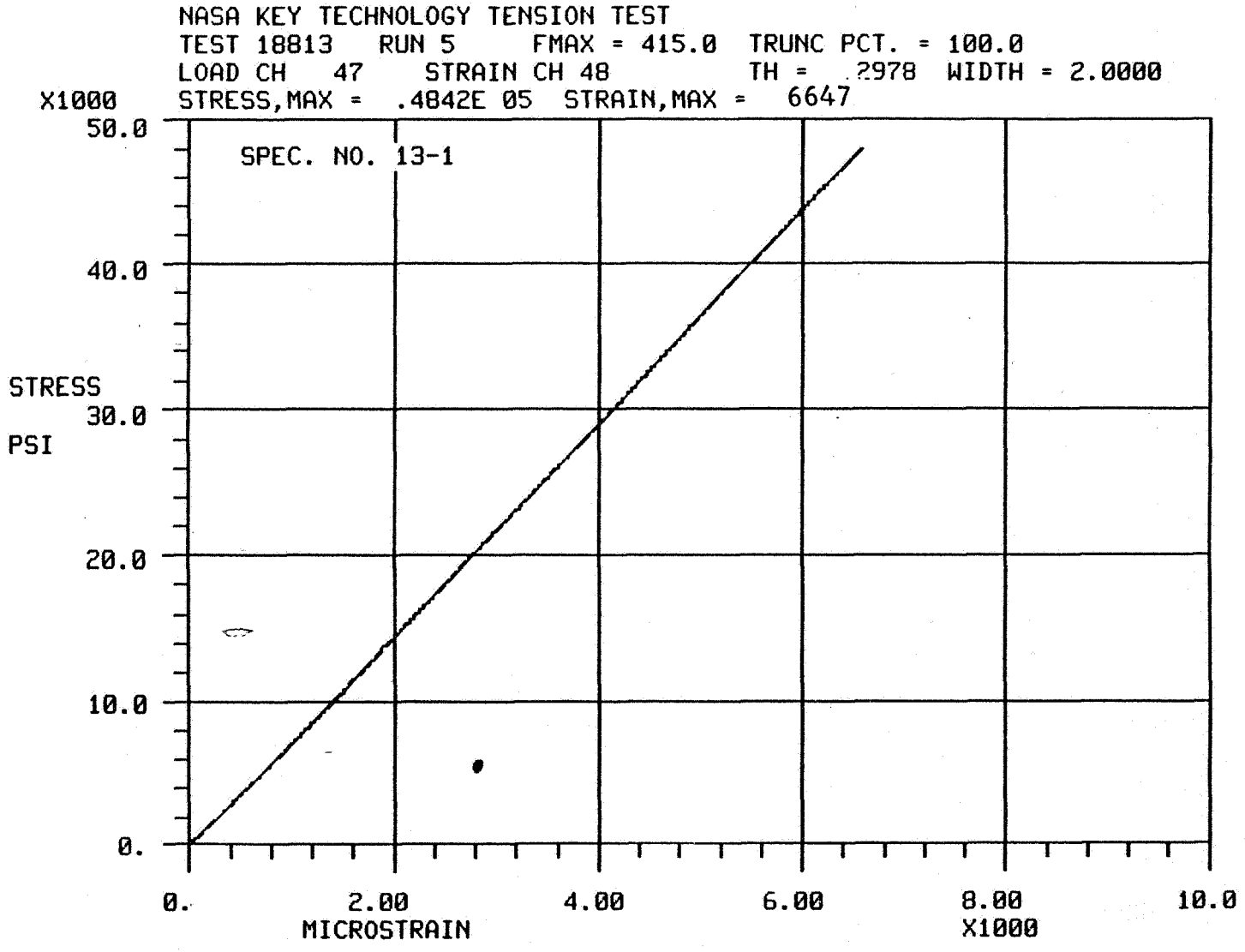

KEY TECHNOLOGY, SANDIFER
TEST # 19899
TEST DATE: 08/19/82 1114
COUPON# 2-5-13B2, FAILURE
X-AXIS Y-AXIS
VAR. CH=53 ,RN=1
MAX. -69.85 .2000E 05
MIN. -.7145E 05 -.1191E 05
CHAN # 55
RUN # 1
CHAN # 56
RUN # 1
A
B
4
X10
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
STRAIN
-8
-6
-4
-2
0
X10 4
STRESS

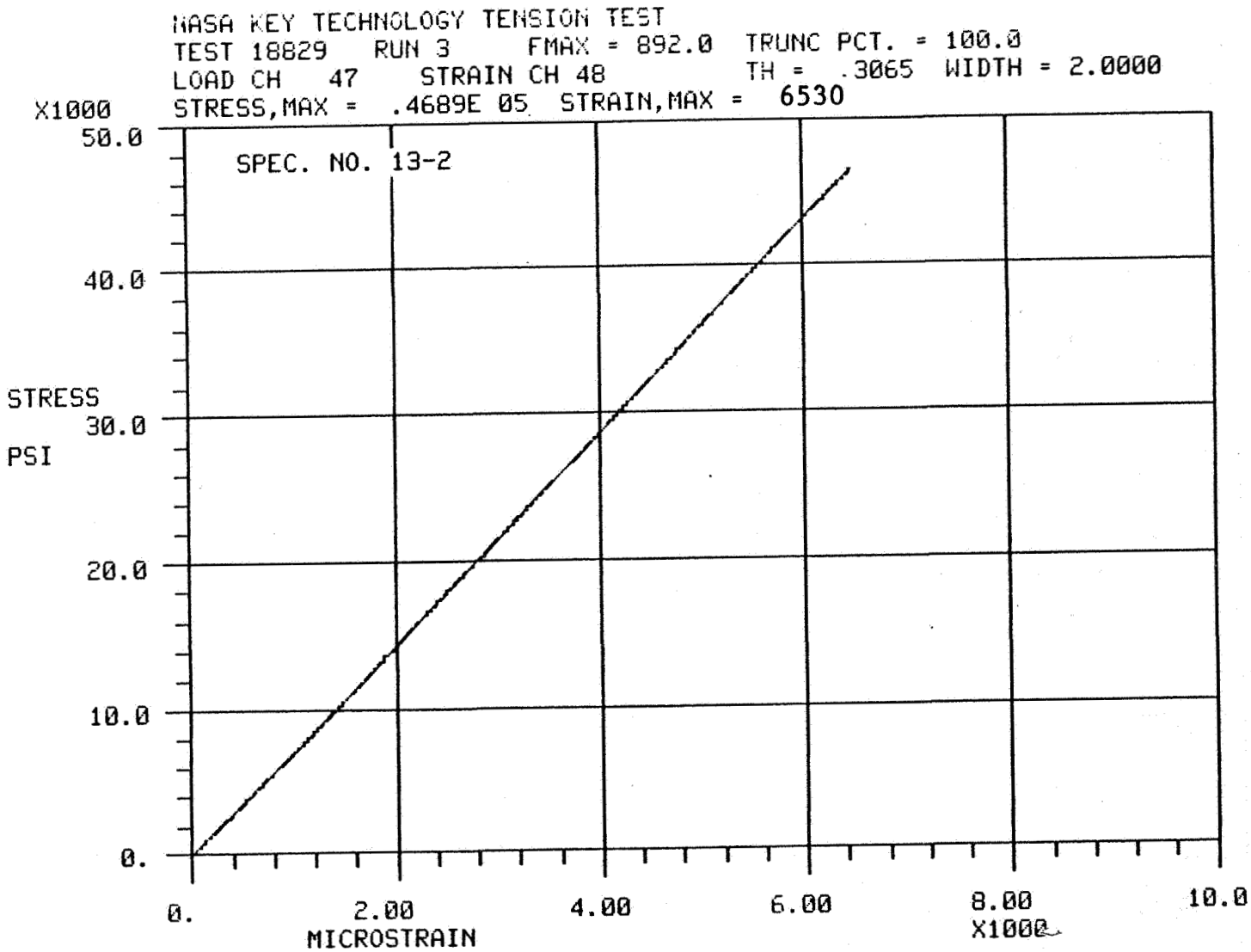
APPENDIX A-3


NASA KEY TECHNOLOGY TENSION TEST
TEST 18846 RUN 2 FMAX = 888.0 TRUNC PCT. = 100.0
LOAD CH 47 STRAIN CH 48 TH = .2592 WIDTH = 1.9960
STRESS,MAX = .4989E 05 STRAIN,MAX = 6778
X1000
50.0
SPEC. NO. 12-1
40.0
STRESS
30.0
PSI
20.0
10.0
0.
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000

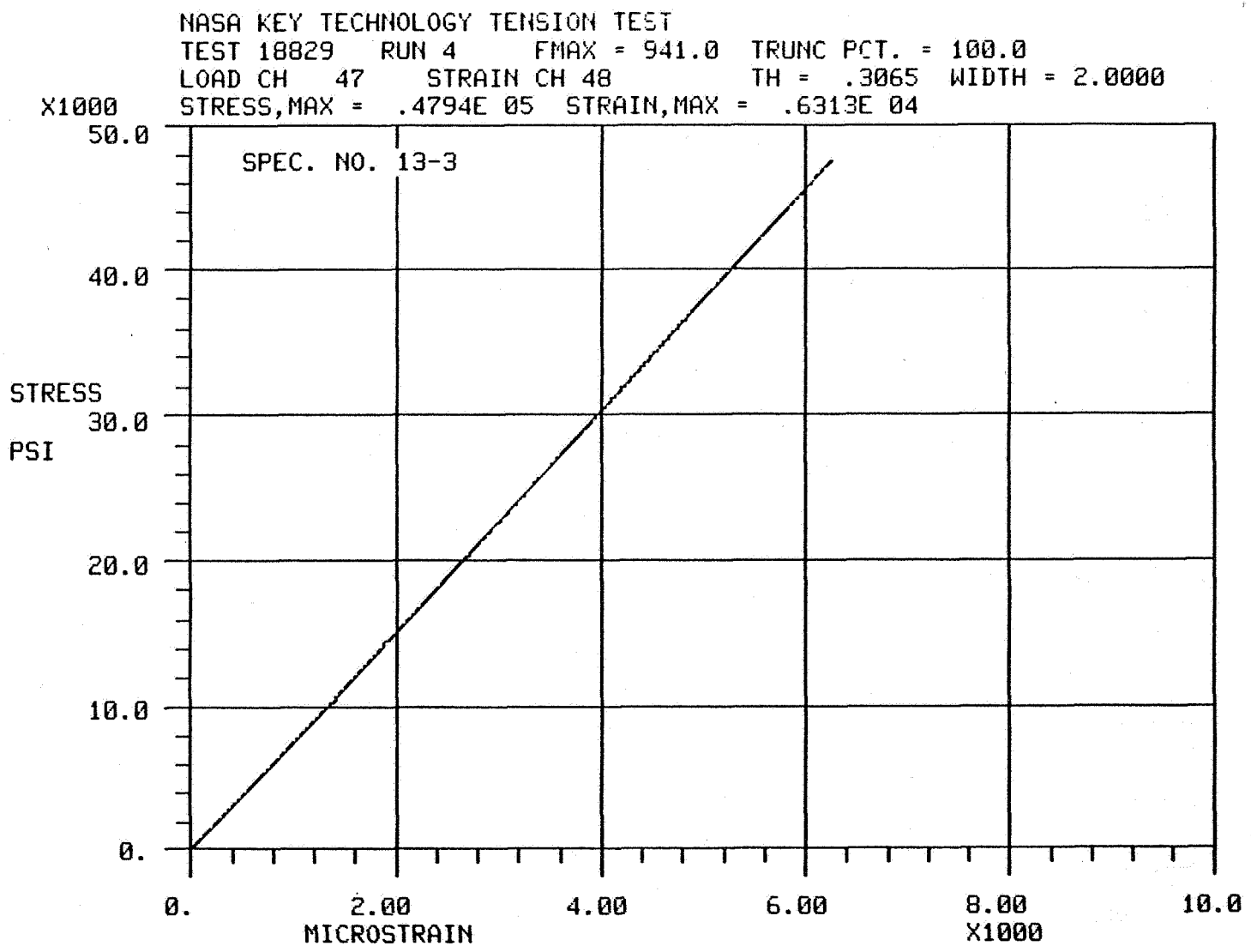

NASA KEY TECHNOLOGY TENSION TEST
TEST 18813 RUN 3 FMAX = 572.0 TRUNC PCT. = 100.0
LOAD CH 47 STRAIN CH 48 TH = 2570 WIDTH = 1.9970
X1000 STRESS,MAX = .4857E 05 STRAIN,MAX = 6474
SPEC. NO. 12-2
50.0
40.0
30.0
20.0
10.0
0.
STRESS
PSI
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000


NASA KEY TECHNOLOGY TENSION TEST
TEST 18813 RUN 4 FMAX = 335.0 TRUNC PCT. = 100.0
LOAD CH 47 STRAIN CH 48 TH = 2564 WIDTH = 1.9990
STRESS,MAX = .4934E 05 STRAIN,MAX = 6918
SPEC. NO. 12-3
X1000
50.0
40.0
30.0
20.0
10.0
0.
STRESS
PSI
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000


NASA KEY TECHNOLOGY TENSION TEST
TEST 18813 RUN 5 FMAX = 415.0 TRUNC PCT. = 100.0
LOAD CH 47 STRAIN CH 48 TH = .2978 WIDTH = 2.0000
STRESS,MAX = .4842E 05 STRAIN,MAX = 6647
X1000
SPEC. NO. 13-1
50.0
40.0
30.0
20.0
10.0
0.
STRESS
PSI
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000



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NASA KEY TECHNOLOGY TENSION TEST
TEST 18829 RUN 4 FMAX = 941.0 TRUNC PCT. = 100.0
LOAD CH 47 STRAIN CH 48 TH = .3065 WIDTH = 2.0000
STRESS,MAX = .4794E 05 STRAIN,MAX = .6313E 04
SPEC. NO. 13-3
X1000
50.0
40.0
30.0
20.0
10.0
0.
STRESS
PSI
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000

APPENDIX B1

AS4/3502 LAMINATE DATA

Description								QA Data				Process Data											
I.D.	No. Plies	% 0°	% ±45°	% 90°	Length (in.)	Width (in.)	Initial Resin Content (6) (%)	NDI "C"Scan	Cured Resin Content (%)	Thickness Per Ply (mils)	Interlam Tension (psi)	Cure Cycle Req.	No. Peel	Bleeder 120	Plies 181	Time to 230°F (min)	Rate (°F/min)	Time to 250°F (min)	Time to 270°F/(min)	Rate to Dwell (°F/min)	Time to 80 psi (min)	Bleeder Resin Content (%)
1	48	25	50	25	26	24	37	OK	29.7	5.35	2270	A	1	0	5	90	1.2	160	(3)	0.81	238	35.8
2	48	25	50	25	26	24	37	OK	29.7	5.39	1900	A	1	0	5	90	1.2	160	(3)	0.81	238	36.4
3	48	25	50	25	26	24	37	OK	28.9	5.50	1960	A	1	0	5	90	1.1	160	(3)	0.81	238	30.0
B4	48	25	50	25	26	24	39	OK	34.9	5.66	(5)	B	1	0	5	74	1.6	97	130	1.2	163	27.3
B5	48	25	50	25	26	24	39	BAD	32.0	5.64	1298	B	1	0	5	90	1.6	120	180	1.0	195	31.1
8	96	25	50	25	26	24	39	OK	37.2	5.65	1425	B	1	0	11	84	1.5	110	144	1.2	163	24.7
9	96	25	50	25	26	24	39	BAD	33.9	5.26	2938	B	1	0	11	85	1.7	115	140	1.3	130	25.6
14	47	40.4	51.1	8.5	68	24	37	BAD	33.3	5.31	1473	B	1	0	5	64	2.3	80	120	1.5	110	30.3
15	48	41.7	50	8.3	68	24	37	BAD	35.1	5.54	2142	B	1	0	5	56	2.4	70	110	1.6	135	31.7
16	48	41.7	50	8.3	68	24	37	OK	35.1	5.84	2283	B	1	0	5	60	2.2	90	135	1.3	118	30.7
17	12	0	100	0	21	12	38	OK	31.5	5.42	2408	B	1	0	1	42	3.1	55	120	1.4	118	30.9
19	11	0	73(1)	27	36	16	36	OK	27.8	5.18	1822	B	1	0	2	50	2.5	70	130	1.3	130	26.9
20	8	25	50(2)	25	36	16	36	OK	27.1	5.00	1990	B	1	0	2	38	3.3	52	100	1.6	130	31.3
21	12	100	0	0	30	26	36	OK	28.4	4.92	2353	B	2	0	1	60	2.2	80	140	1.2	135	28.4
22	48	41.7	50	8.3	40	24	39	BAD	32.2	5.52	1403	B	1	0	5	70	1.9	100	140	1.2	160	32.8
24	20	10	80	10	40	24	38	OK	30.5	5.70	2567	B	1	0	2	60	2.2	88	135	1.3	118	32.5
25	20	10	80	10	40	24	38	OK	29.0	5.95	2450	B	1	0	2	54	2.5	70	110	1.6	135	33.1
26	20	10	80	10	40	24	38	OK	26.8	5.35	2725	B	1	0	2	55	2.6	68	90	2.1	110	33.6
27	20	10	80	10	40	24	38	OK	29.6	5.40	2317	B	1	0	3	50	2.4	80	130	1.2	158	30.7
28	28	21.4	71.4	7.2	40	24	38	OK	28.4	5.50	2142	B	1	0	3	50	2.4	80	130	1.2	158	32.2
29	28	21.4	71.4	7.2	40	24	38	OK	29.3	5.68	2650	B	1	0	3	55	2.6	68	90	2.1	110	32.0
30	48	41.7	50	8.3	40	24	39	OK	30.9	5.60	2258	B	1	0	6	100	1.4	130	200	0.90	195	29.8
31	48	41.7	50	8.3	40	24	39	BAD	32.5	5.73	1903	B	1	0	5	90	1.4	120	200	0.82	195	30.3
QA1	32	25	50	25	24	24	40	BAD	36.2	5.69	(5)	A	3	0	0	57	2.4	68	(3)	2.4	130	(5)
QA2	32	25	50	25	24	24	40	BAD	35.8	6.09	(5)	A	2	1	0	52	2.0	65	(3)	2.0	135	(5)
QA3	32	25	50	25	24	24	40	OK	29.2	5.19	(5)	A	2	1	2	55	2.0	70	(3)	2.0	152	(5)
101	48	12.5	75	12.5	68	24	39	BAD	34.8	5.38	(5)	C	2	0	6	80	1.7	130	160	1.1	130	28.0
101A	48	12.5	75	12.5	68	24	39	BAD	34.6	5.82	2377	B	2	0	6	45	2.8	50	(4)	3.3	85	(5)
102	48	12.5	75	12.5	40	24	39	BAD	31.9	5.44	3050	C	2	0	6	80	1.7	130	160	1.1	130	29.6
104	48	41.7	50	8.3	40	24	39	BAD	31.4	5.42	2533	C	2	0	6	80	1.6	130	160	1.0	130	29.8

BATCH 2026

(1) ±30°.
(2) ±35°.
(3) 250°F Dwell.
(4) 260°F Dwell.
(5) Not available.
(6) Calculated from cert. data.

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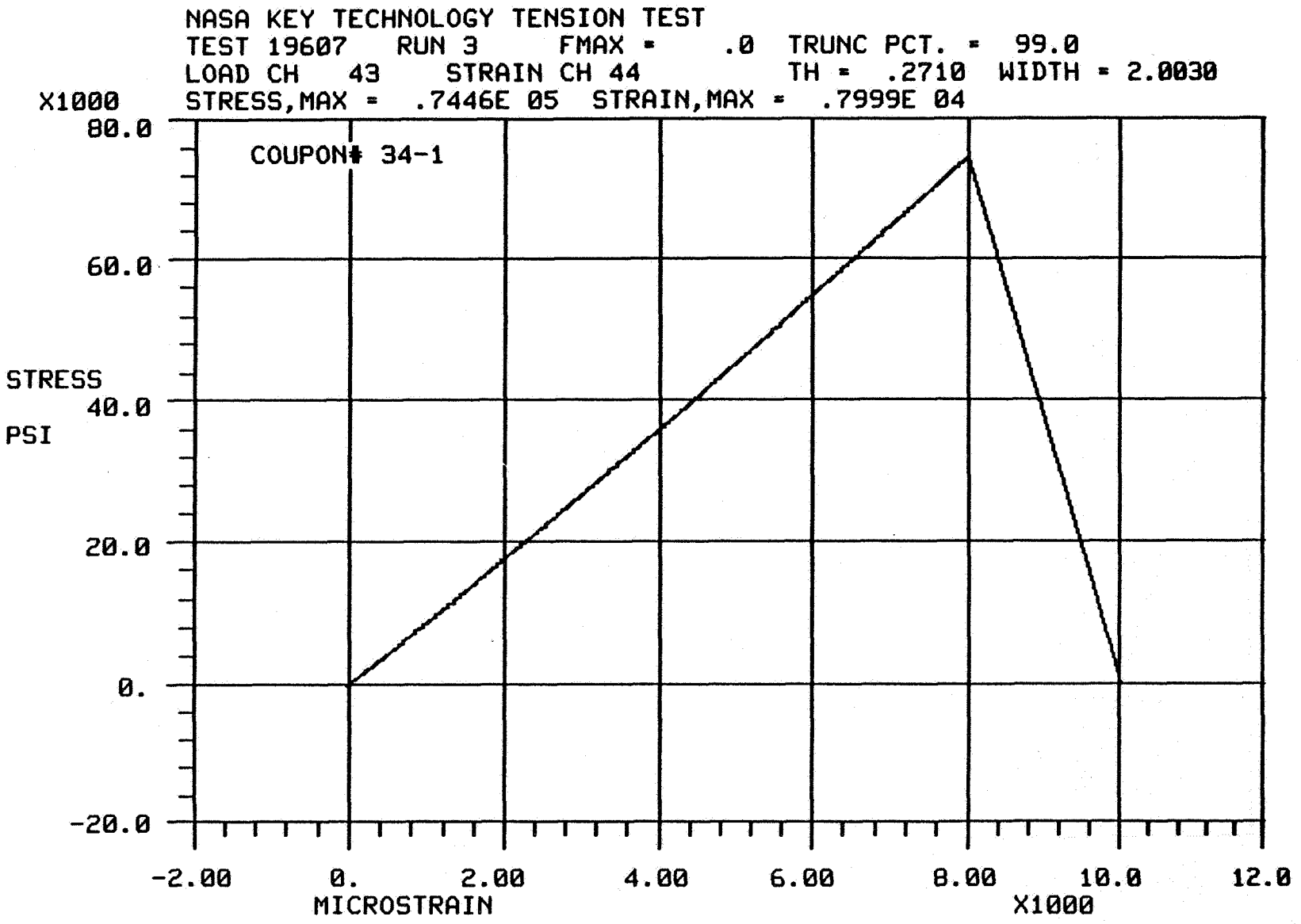
AS4/2220-1 LAMINATE DATA

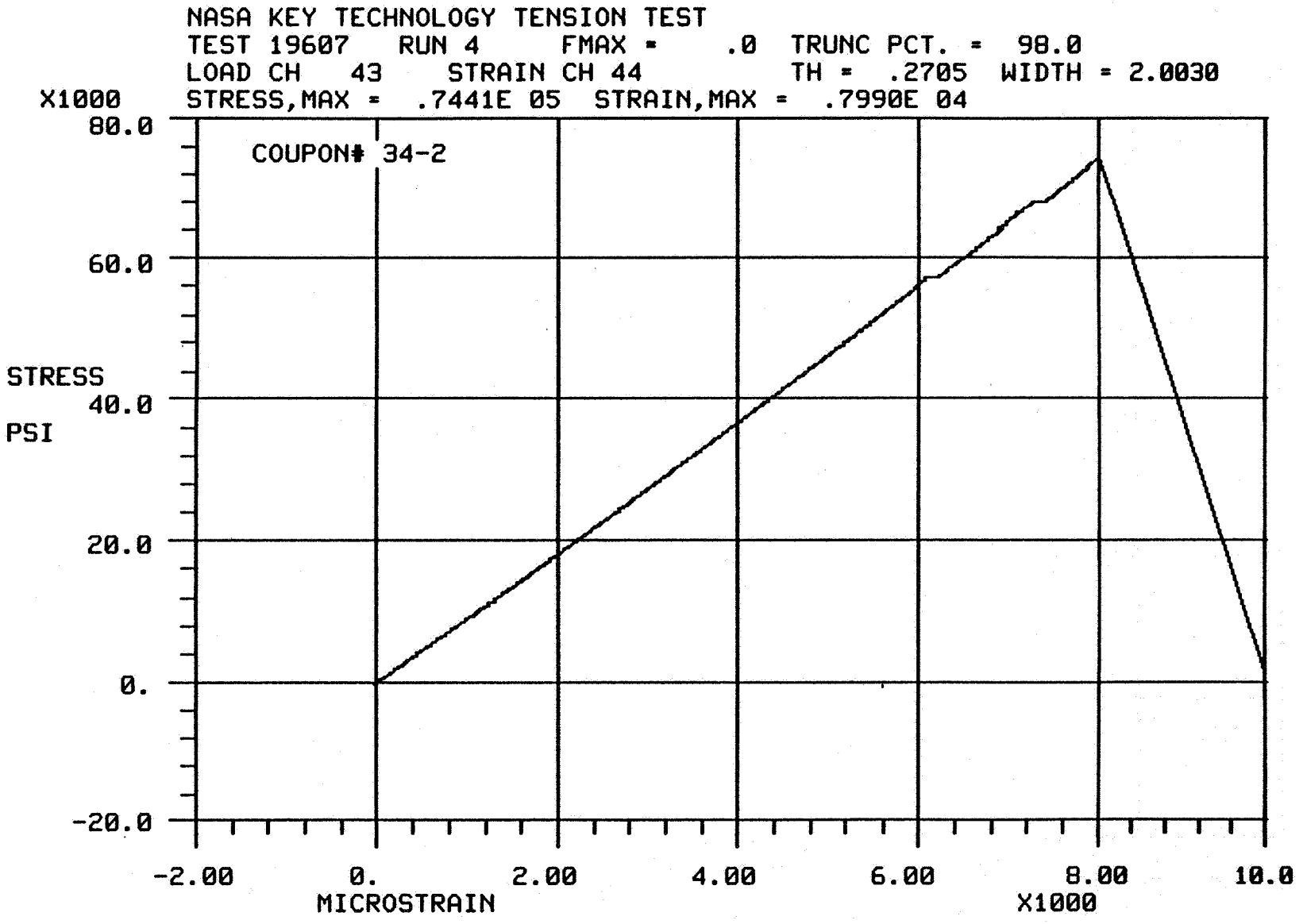
Description								QA Data				Process Data									
I.D.	No. Plies	% 0°	% ±45°	% 90°	Length (in.)	Width (in.)	Initial Resin Content (4) (%)	NDI "C"Scan	Resin Content (%)	Thickness Per Ply (mils)	Interlam Tension (psi)	Cure Cycle Req.	No. Peel	Bleeder 120	Plies 181	Time to 210°F (min)	Rate (°F/min)	Time to 225°F (min)	Rate to 225°F (°F/min)	Time to 80 psi (min)	Bleeder Resin Content (%)
1A	48	25	50	25	26	24	35	OK	33.9	5.57	2633	A	1	0	2	115	0.87	173	0.66	192	21.7
4	48	25	50	25	26	24	35	BAD	34.7	5.60	(3)	B	1	0	2	66	1.5	86	1.34	195	21.1
5	48	25	50	25	26	24	35	BAD	35.0	5.64	(3)	B	1	0	2	66	1.5	86	1.34	195	23.9
10	96	25	50	25	26	24	34	BAD	(3)	5.62	(3)	A	1	0	5	103	0.92	155	0.71	255	(3)
10A	96	25	50	25	26	24	34	OK	36.0	5.49	2110	A	1	0	5	110	0.86	155	0.71	163	14.0
11	48	25	50	25	26	24	34	BAD	(3)	5.65	(3)	A	1	0	2	93	1.0	155	0.71	255	11.0
11A	48	25	50	25	26	24	34	OK	33.8	5.54	2597	A	1	0	2	113	1.0	136	0.96	133	23.8
12	48	25	50(5)	25	80	30	34	OK	34.3	5.49	2783	A	1	0	2	114	1.0	137	0.95	133	24.4
34	48	41.7	50	8.3	68	24	36	OK	34.5	5.54	2295	A	1	0	2	103	1.1	113	1.11	132	30.3
35	48	41.7	50	8.3	68	24	36	OK	35.0	5.51	2658	A	1	0	2	103	0.97	113	1.02	132	29.6
36	48	41.7	50	8.3	68	24	36	OK	35.8	5.54	2170	A	1	0	2	97	1.2	136	0.96	123	27.7
37	12	0	100	0	21	12	35	OK	29.8	5.21	2050	A	2	1	0	72	1.5	93	1.34	115	42.3
38	12	100	0	0	30	26	35	OK	30.8	4.83	2062	A	1	1	0	84	1.3	98	1.28	115	29.7
39	11	0	72.7(1)	27.3	36	16	35	OK	28.6	5.57	2108	A	1	1	0	68	1.6	89	1.40	115	40.8
40	8	25	50 (2)	25	36	16	35	OK	29.6	5.42	2253	A	1	1	0	63	2.0	92	1.52	115	38.4
41	48	25	50 (5)	25	24	30	37	OK	30.5	5.48	2808	A	1	0	2	76	1.4	96	1.25	100	(3)
QA1	32	25	50	25	24	24		BAD	(3)	(3)	(3)	C	2	1	1	..	..	..	..	..	(3)
QA2	32	25	50	25	24	24		OK	34.5	5.4	(3)	A	2	1	1	..	..	..	..	..	(3)

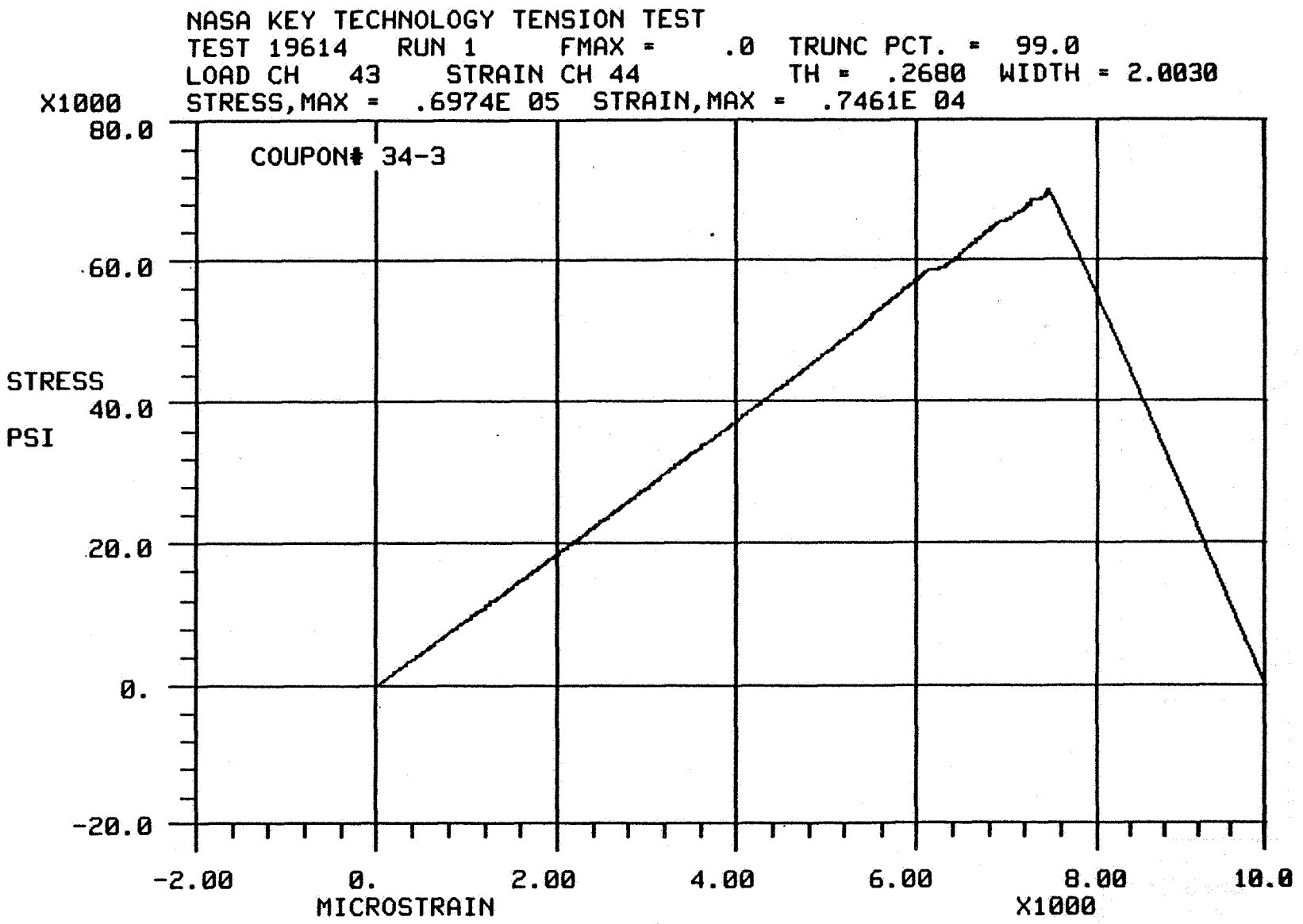
BATCH 2029 AND BATCH 2163

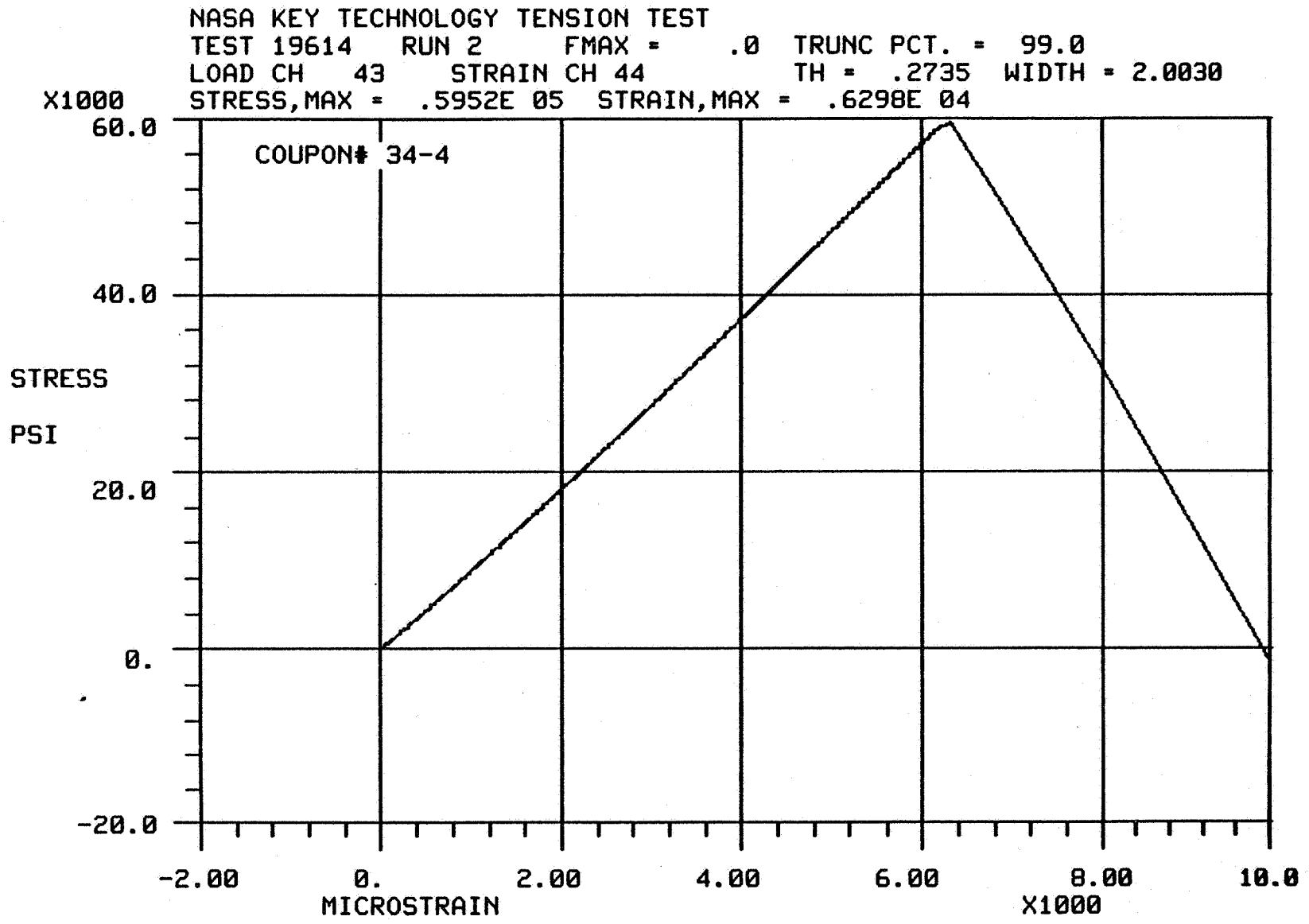
(1) ±30°.
(2) ±35°.
(3) Not available.
(4) Calculated from cert. data.
(5) Unidirectional material used.

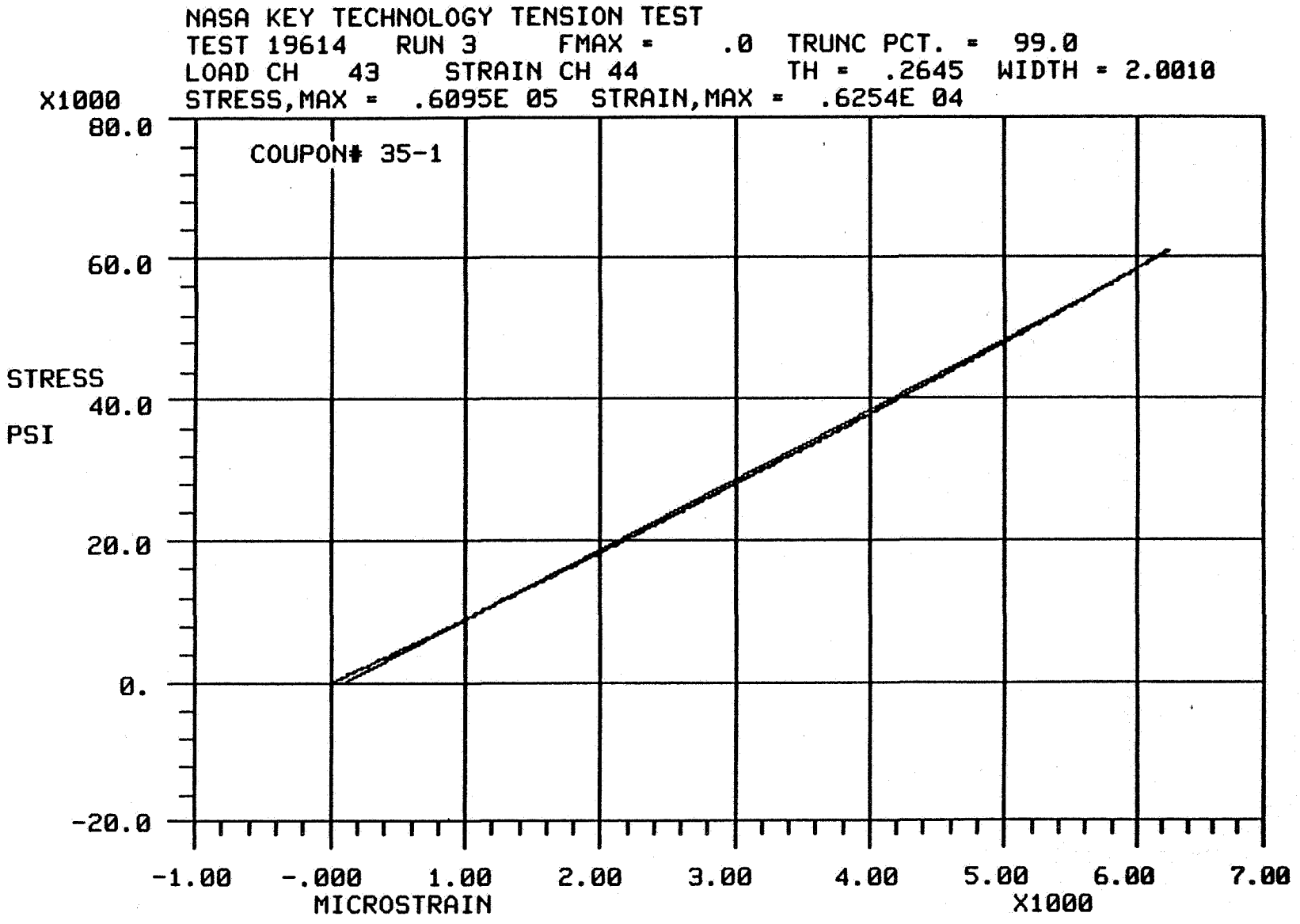
APPENDIX B2

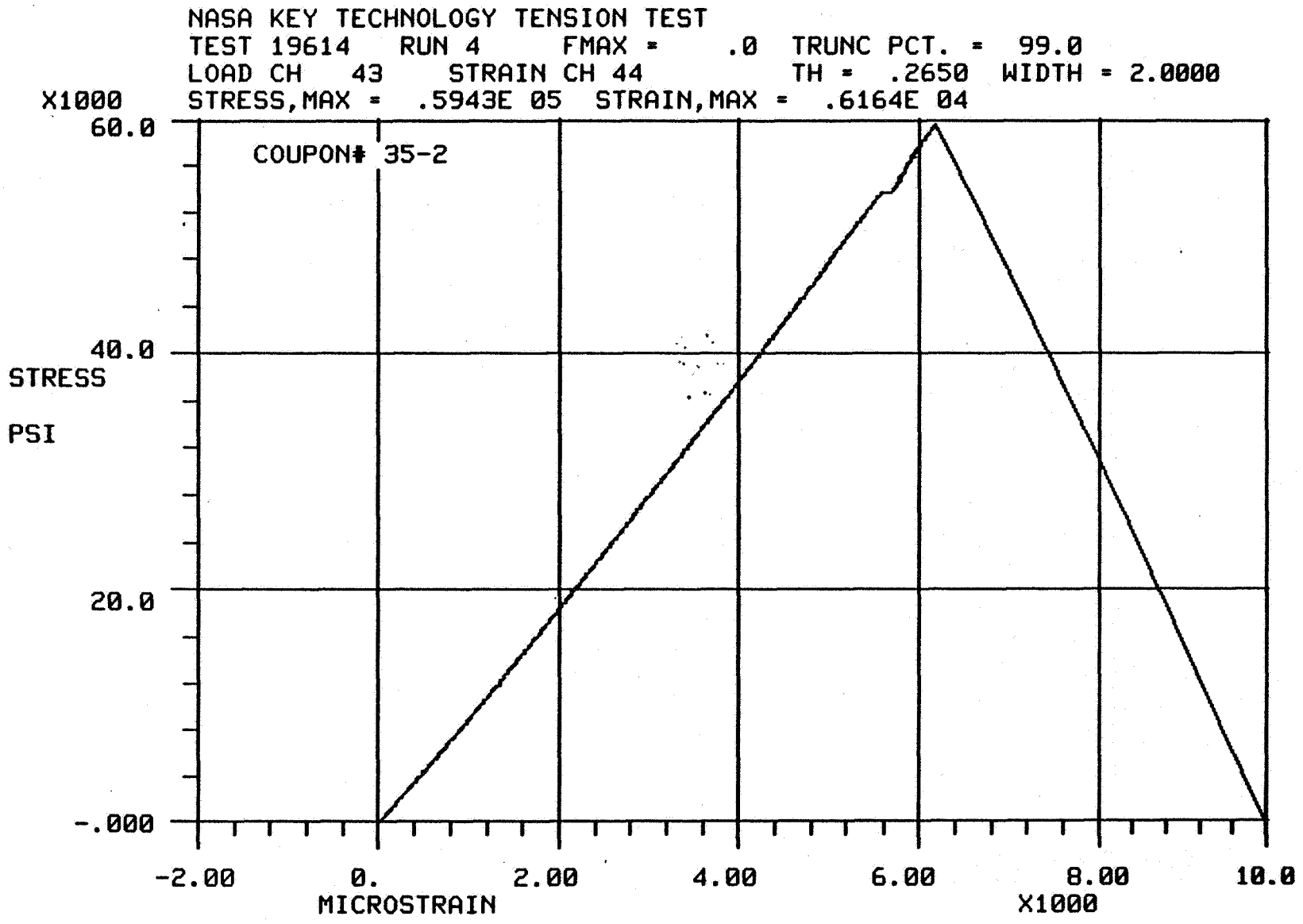

NASA KEY TECHNOLOGY TENSION TEST
TEST 19607 RUN 3 FMAX = .0 TRUNC PCT. = 99.0
LOAD CH 43 STRAIN CH 44 TH = .2710 WIDTH = 2.0030
X1000 STRESS,MAX = .7446E 05 STRAIN,MAX = .7999E 04
COUPON# 34-1
80.0
60.0
40.0
20.0
0.
-20.0
STRESS
PSI
-2.00
0.
2.00
4.00
6.00
8.00
10.0
12.0
MICROSTRAIN
X1000

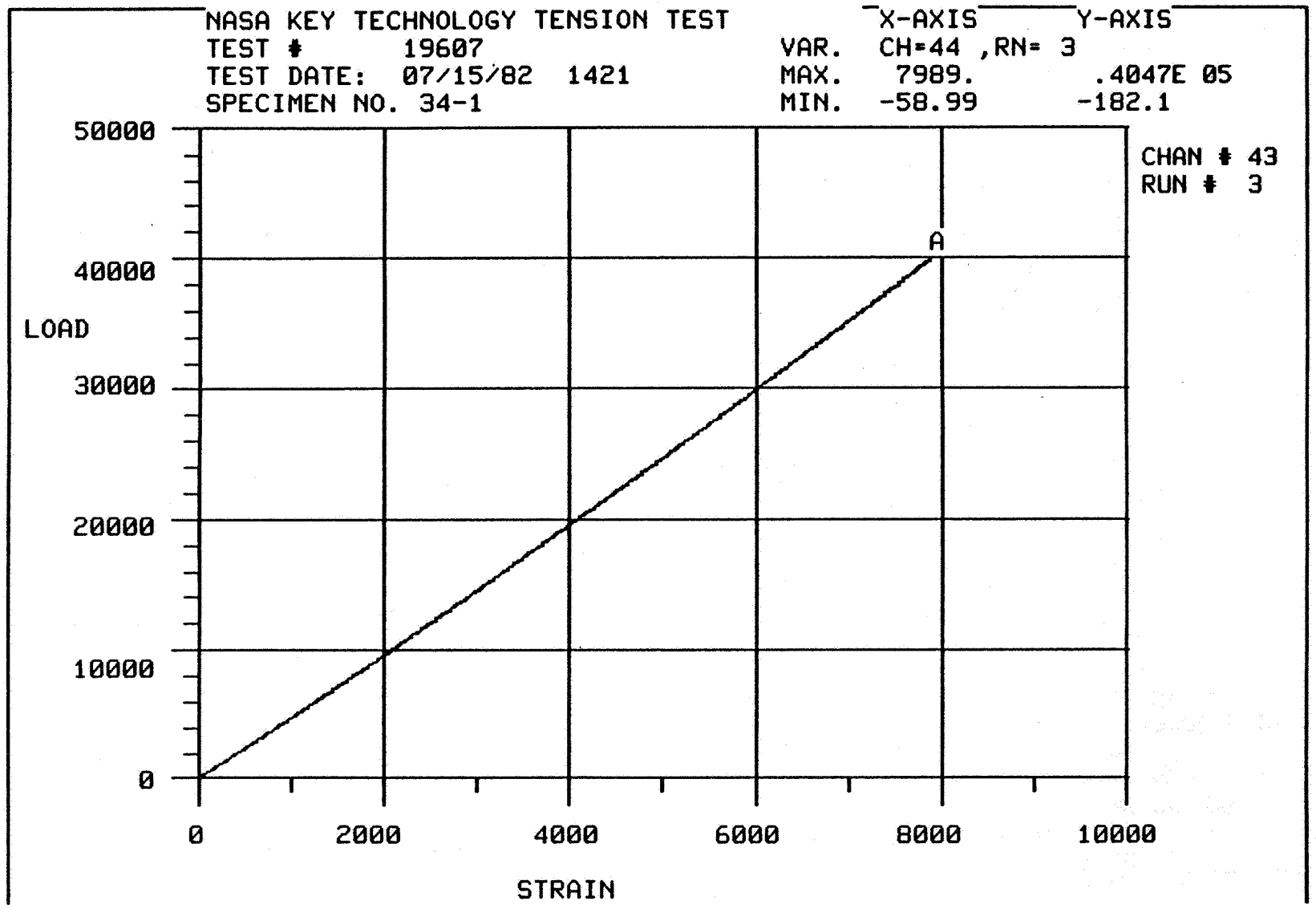

NASA KEY TECHNOLOGY TENSION TEST
TEST 19607 RUN 4 FMAX = .0 TRUNC PCT. = 98.0
LOAD CH 43 STRAIN CH 44 TH = .2705 WIDTH = 2.0030
X1000 STRESS,MAX = .7441E 05 STRAIN,MAX = .7990E 04
COUPON# 34-2
80.0
60.0
40.0
20.0
0.
-20.0
STRESS
PSI
-2.00
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000

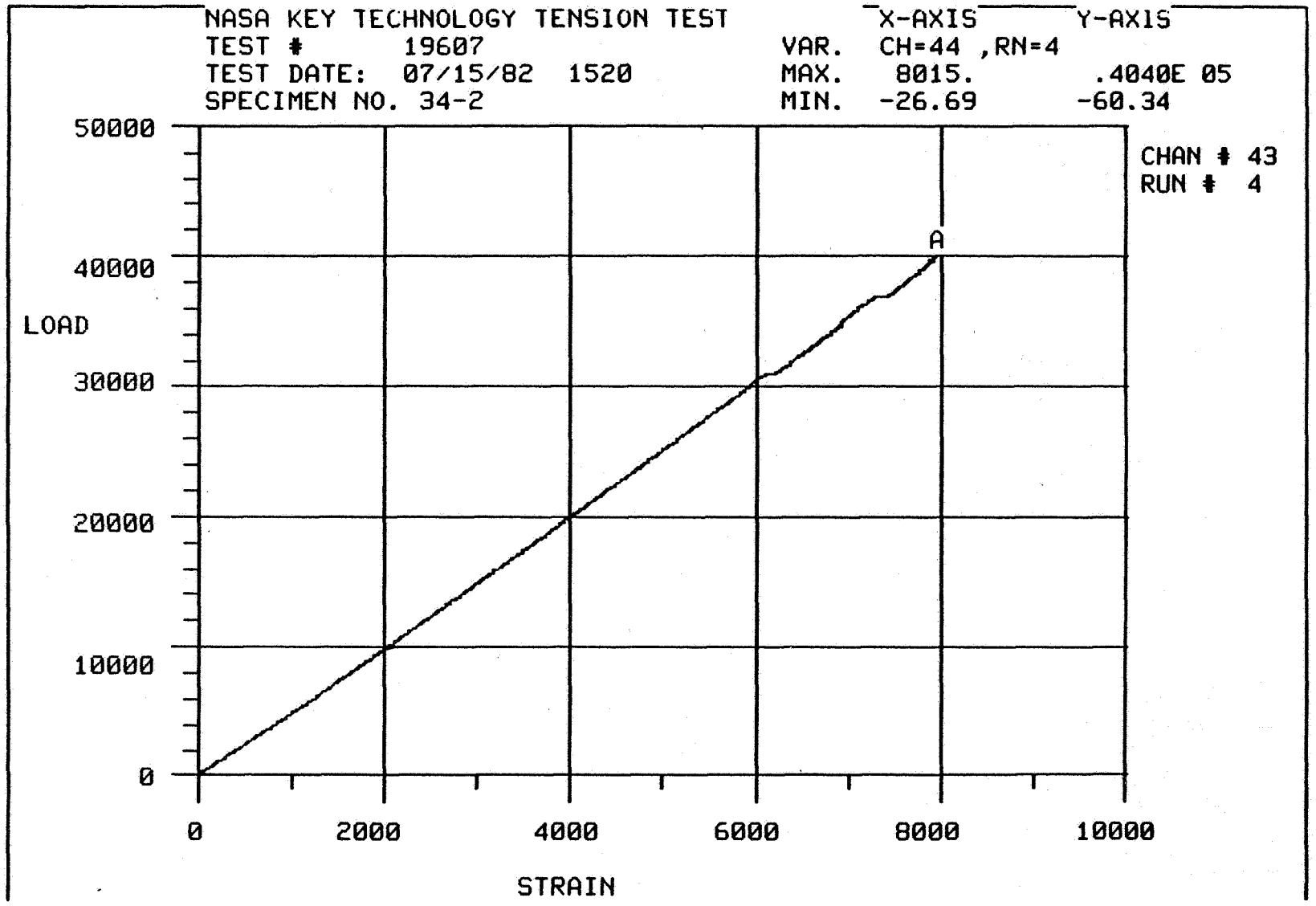

NASA KEY TECHNOLOGY TENSION TEST
TEST 19614 RUN 1 FMAX = .0 TRUNC PCT. = 99.0
LOAD CH 43 STRAIN CH 44 TH = .2680 WIDTH = 2.0030
X1000 STRESS,MAX = .6974E 05 STRAIN,MAX = .7461E 04
COUPON# 34-3
80.0
60.0
40.0
20.0
0.
-20.0
STRESS
PSI
-2.00
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000

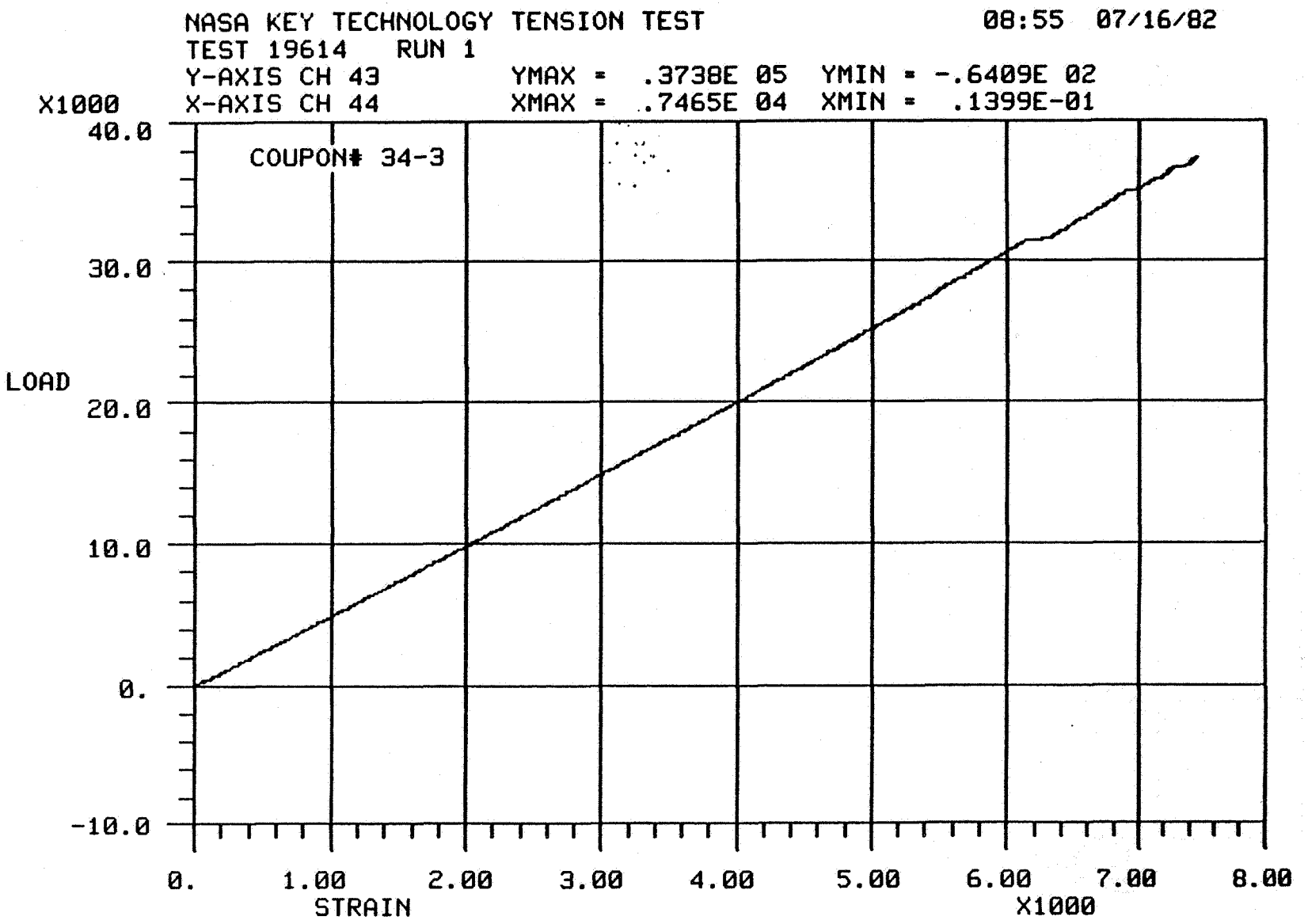

NASA KEY TECHNOLOGY TENSION TEST
TEST 19614 RUN 2 FMAX = .0 TRUNC PCT. = 99.0
LOAD CH 43 STRAIN CH 44 TH = .2735 WIDTH = 2.0030
STRESS,MAX = .5952E 05 STRAIN,MAX = .6298E 04
X1000
60.0
COUPON# 34-4
40.0
STRESS
PSI
20.0
0.
-20.0
-2.00
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000

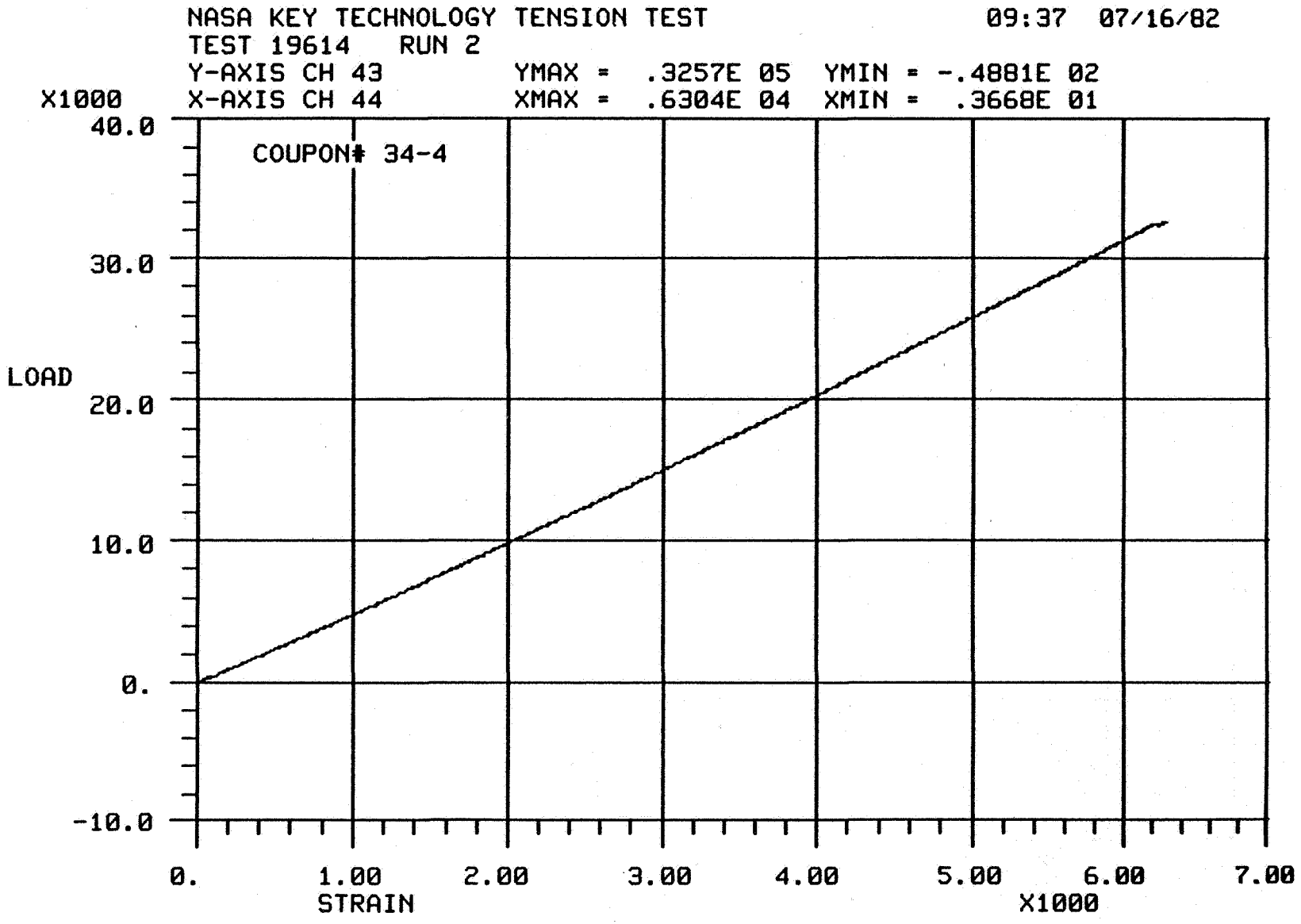

NASA KEY TECHNOLOGY TENSION TEST
TEST 19614 RUN 3 FMAX = .0 TRUNC PCT. = 99.0
LOAD CH 43 STRAIN CH 44 TH = .2645 WIDTH = 2.0010
X1000 STRESS,MAX = .6095E 05 STRAIN,MAX = .6254E 04
COUPON# 35-1
80.0
60.0
40.0
20.0
0.
-20.0
STRESS
PSI
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
6.00
7.00
MICROSTRAIN
X1000

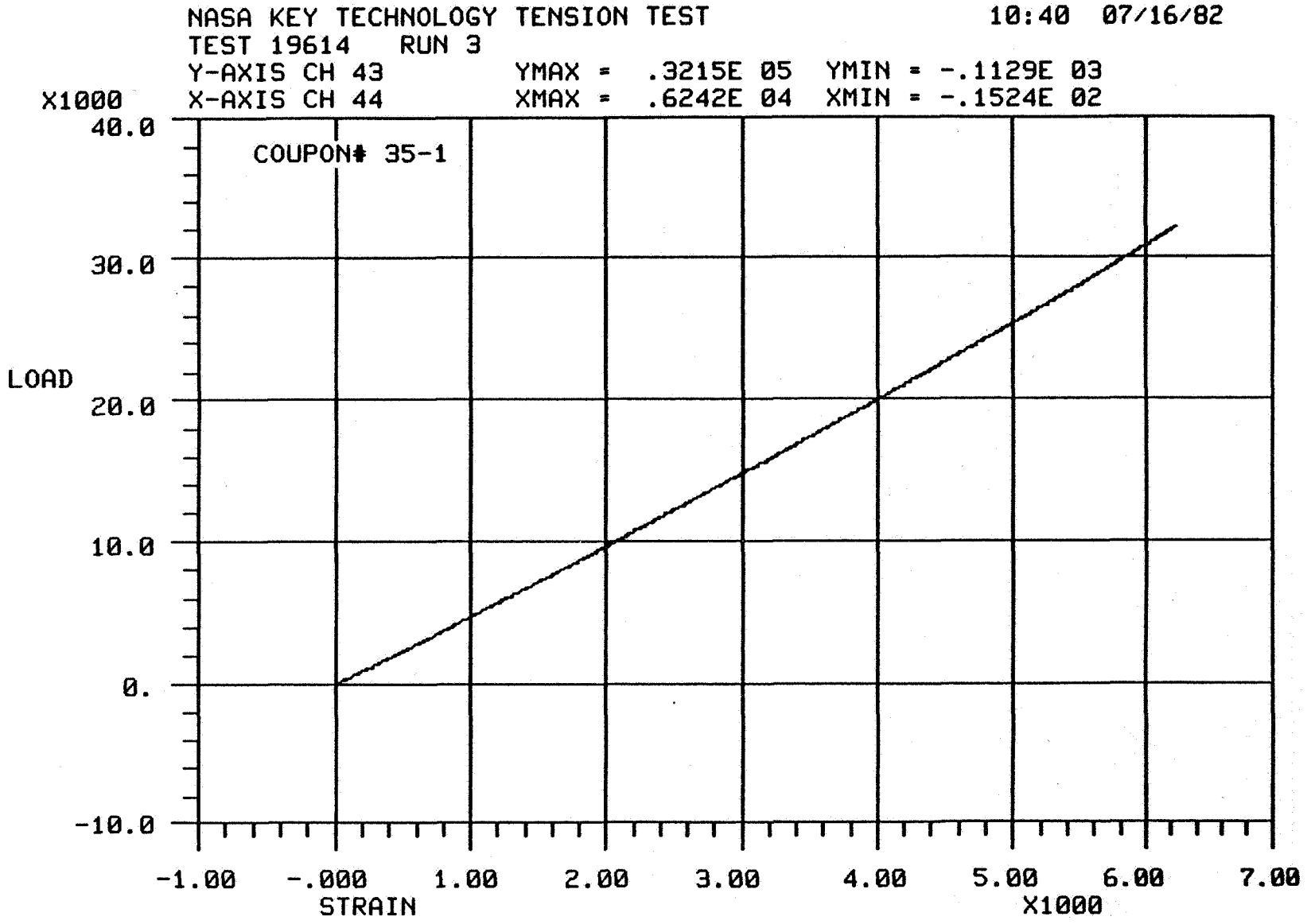

NASA KEY TECHNOLOGY TENSION TEST
TEST 19614 RUN 4 FMAX = .0 TRUNC PCT. = 99.0
LOAD CH 43 STRAIN CH 44 TH = .2650 WIDTH = 2.0000
X1000 STRESS,MAX = .5943E 05 STRAIN,MAX = .6164E 04
COUPON# 35-2
60.0
40.0
STRESS
PSI
20.0
-.000
-2.00
0.
2.00
4.00
6.00
8.00
10.0
MICROSTRAIN
X1000

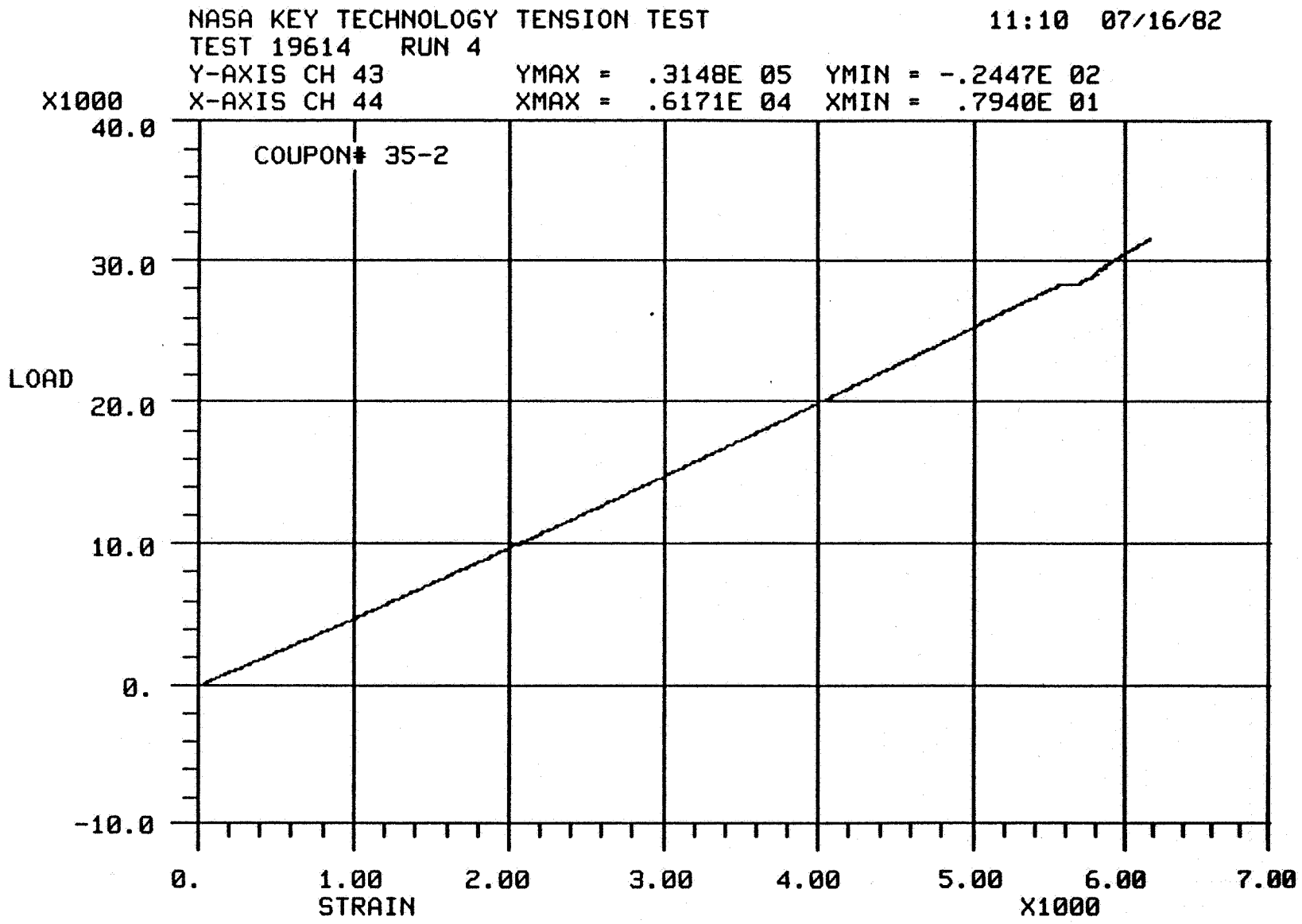

NASA KEY TECHNOLOGY TENSION TEST
TEST # 19607
TEST DATE: 07/15/82 1421
SPECIMEN NO. 34-1
X-AXIS
Y-AXIS
VAR. CH=44 ,RN= 3
MAX. 7989. .4047E 05
MIN. -58.99 -182.1
CHAN # 43
RUN # 3
A
50000
40000
30000
20000
10000
0
LOAD
0
2000
4000
6000
8000
10000
STRAIN

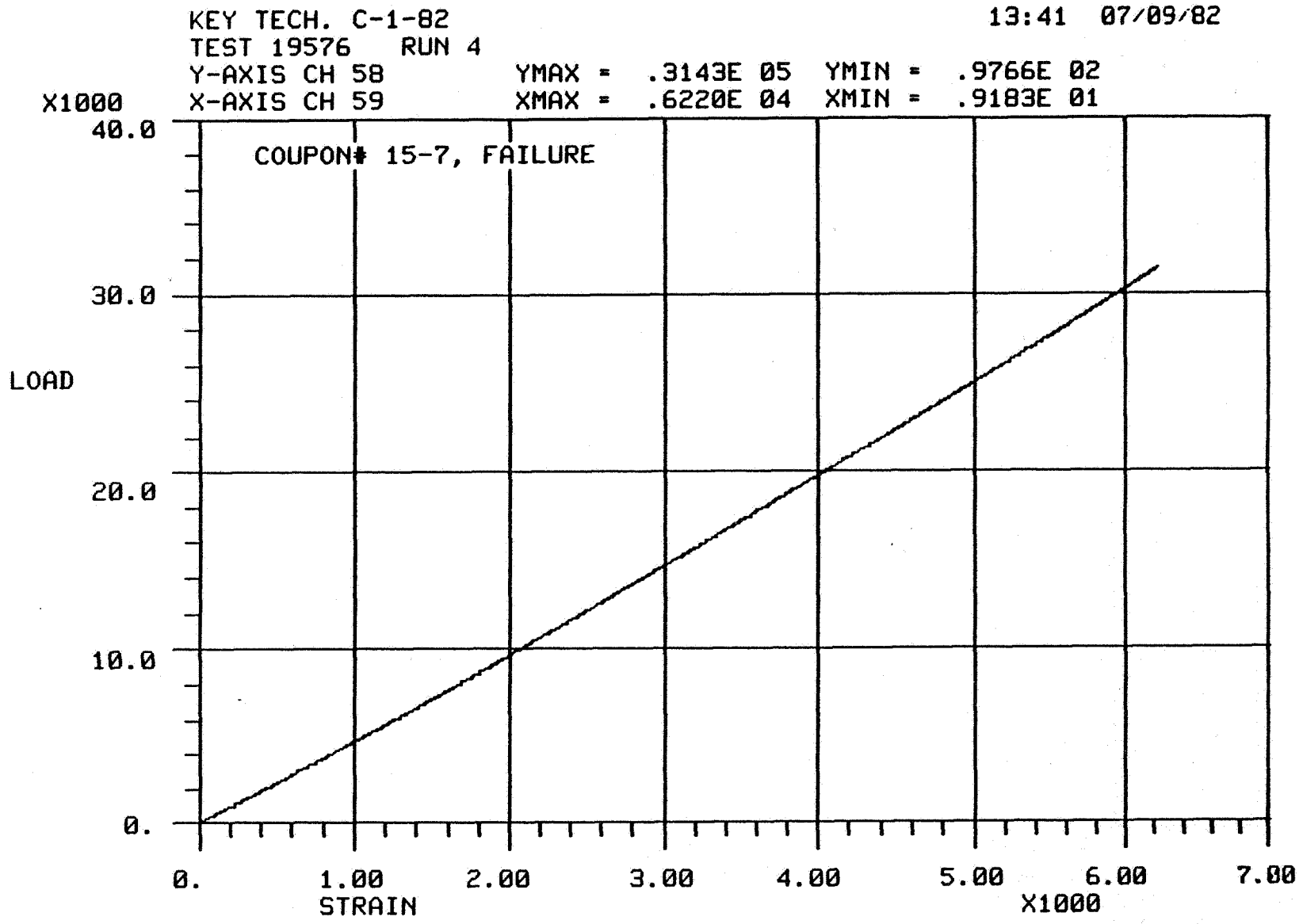

NASA KEY TECHNOLOGY TENSION TEST
TEST # 19607
TEST DATE: 07/15/82 1520
SPECIMEN NO. 34-2
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=4
MAX. 8015. .4040E 05
MIN. -26.69 -60.34
CHAN # 43
RUN # 4
A
50000
40000
30000
20000
10000
0
LOAD
0
2000
4000
6000
8000
10000
STRAIN

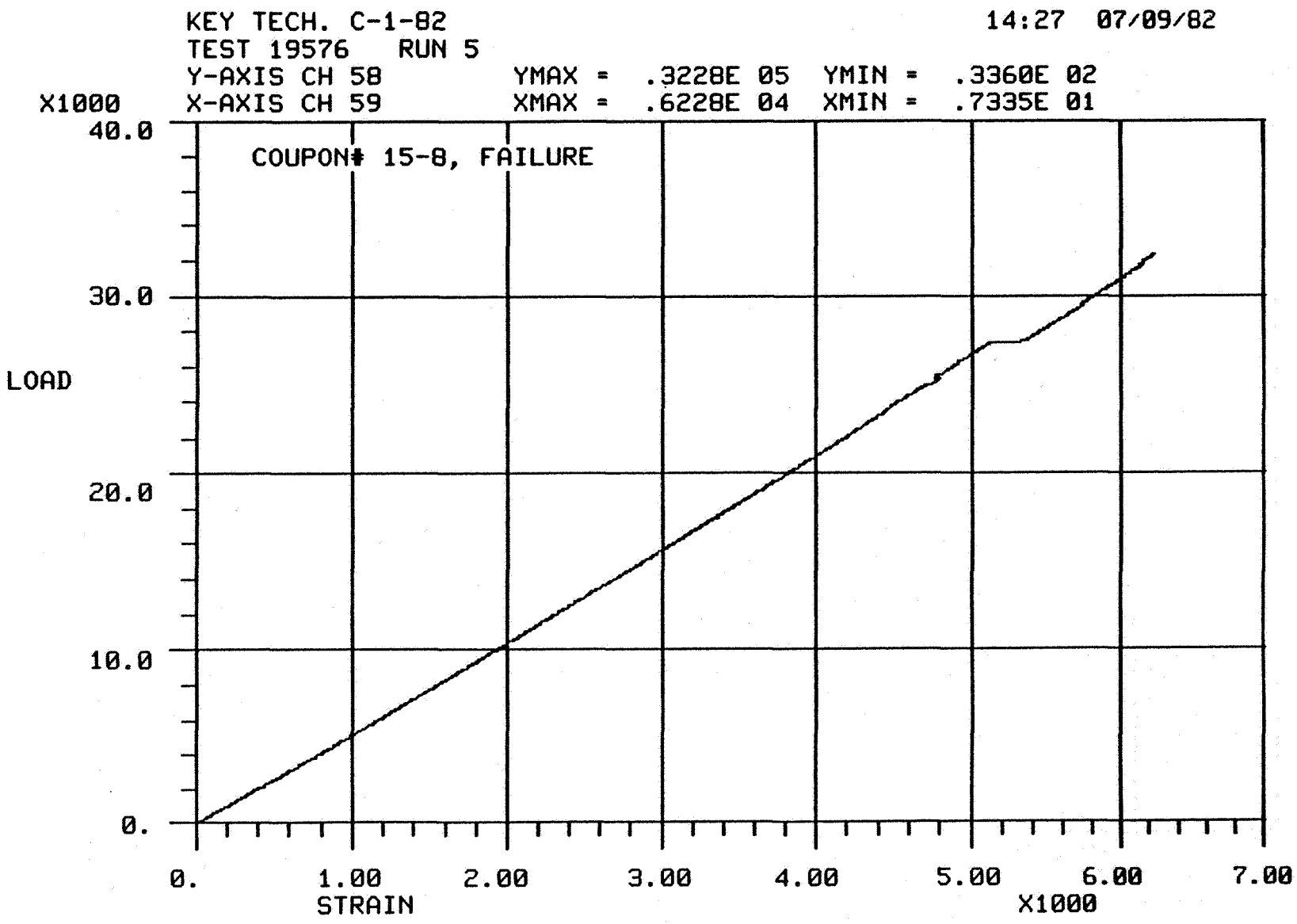

NASA KEY TECHNOLOGY TENSION TEST
08:55 07/16/82
TEST 19614 RUN 1
Y-AXIS CH 43
YMAX = .3738E 05
YMIN = -.6409E 02
X1000
X-AXIS CH 44
XMAX = .7465E 04
XMIN = .1399E-01
COUPON# 34-3
40.0
30.0
20.0
10.0
0.
-10.0
LOAD
0.
1.00
2.00
3.00
4.00
5.00
6.00
7.00
8.00
STRAIN
X1000

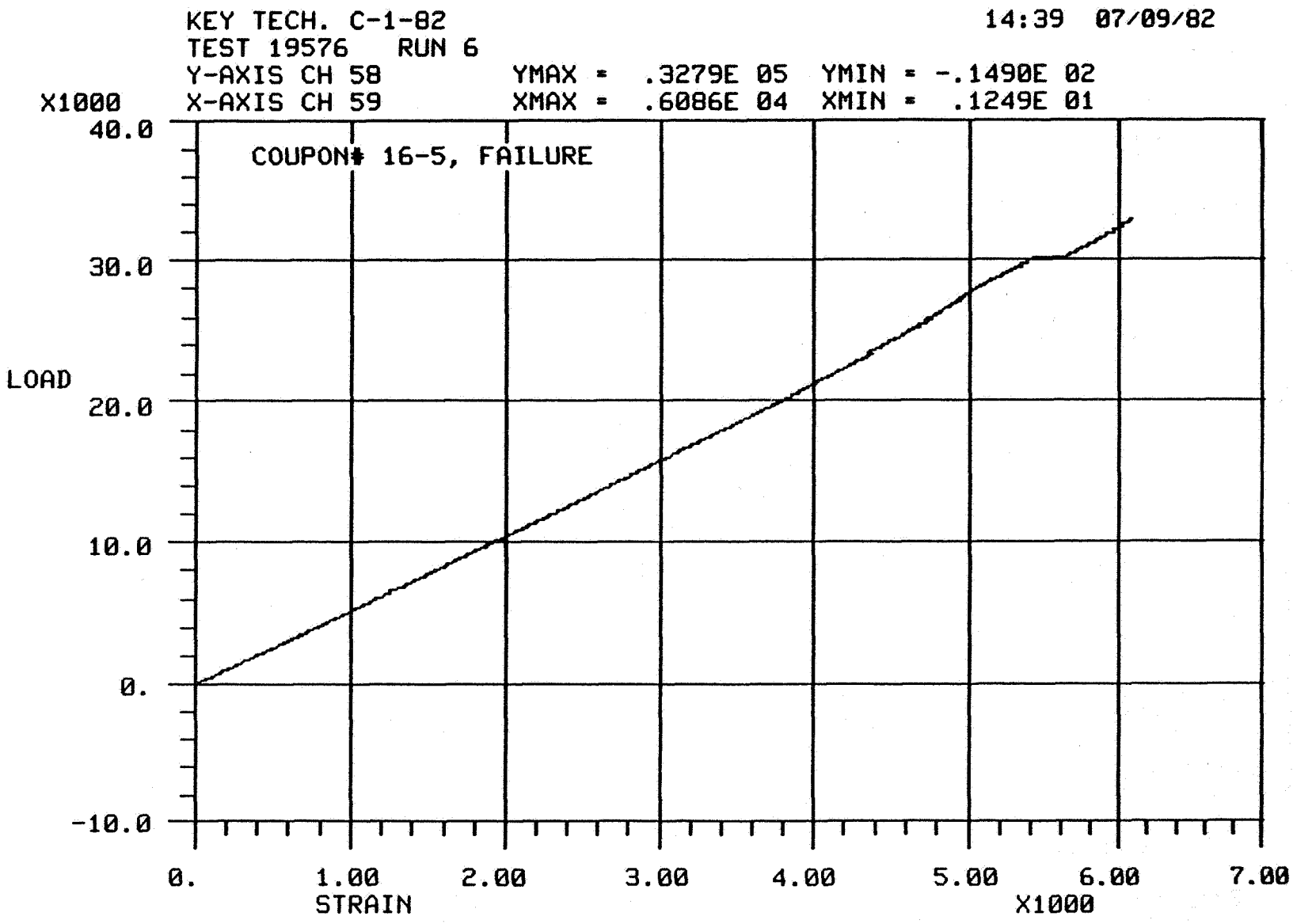

NASA KEY TECHNOLOGY TENSION TEST
09:37 07/16/82
TEST 19614 RUN 2
Y-AXIS CH 43
YMAX = .3257E 05
YMIN = -.4881E 02
X1000
X-AXIS CH 44
XMAX = .6304E 04
XMIN = .3668E 01
40.0
COUPON# 34-4
30.0
LOAD
20.0
10.0
0.
-10.0
0.
1.00
2.00
3.00
4.00
5.00
6.00
7.00
STRAIN
X1000

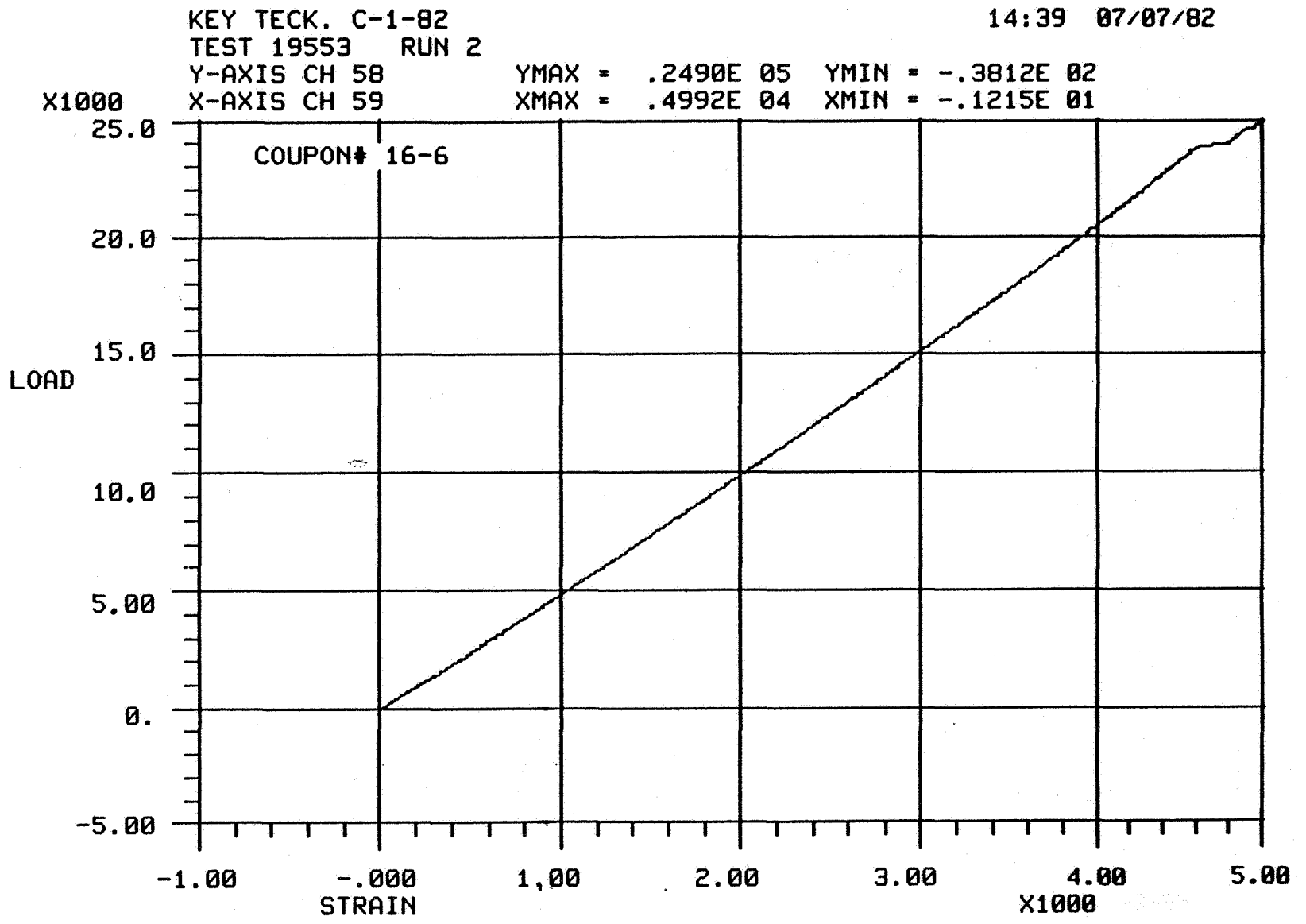

NASA KEY TECHNOLOGY TENSION TEST
10:40 07/16/82
TEST 19614 RUN 3
Y-AXIS CH 43
YMAX = .3215E 05
YMIN = -.1129E 03
X-AXIS CH 44
XMAX = .6242E 04
XMIN = -.1524E 02
X1000
COUPON# 35-1
LOAD
40.0
30.0
20.0
10.0
0.
-10.0
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
6.00
7.00
STRAIN
X1000

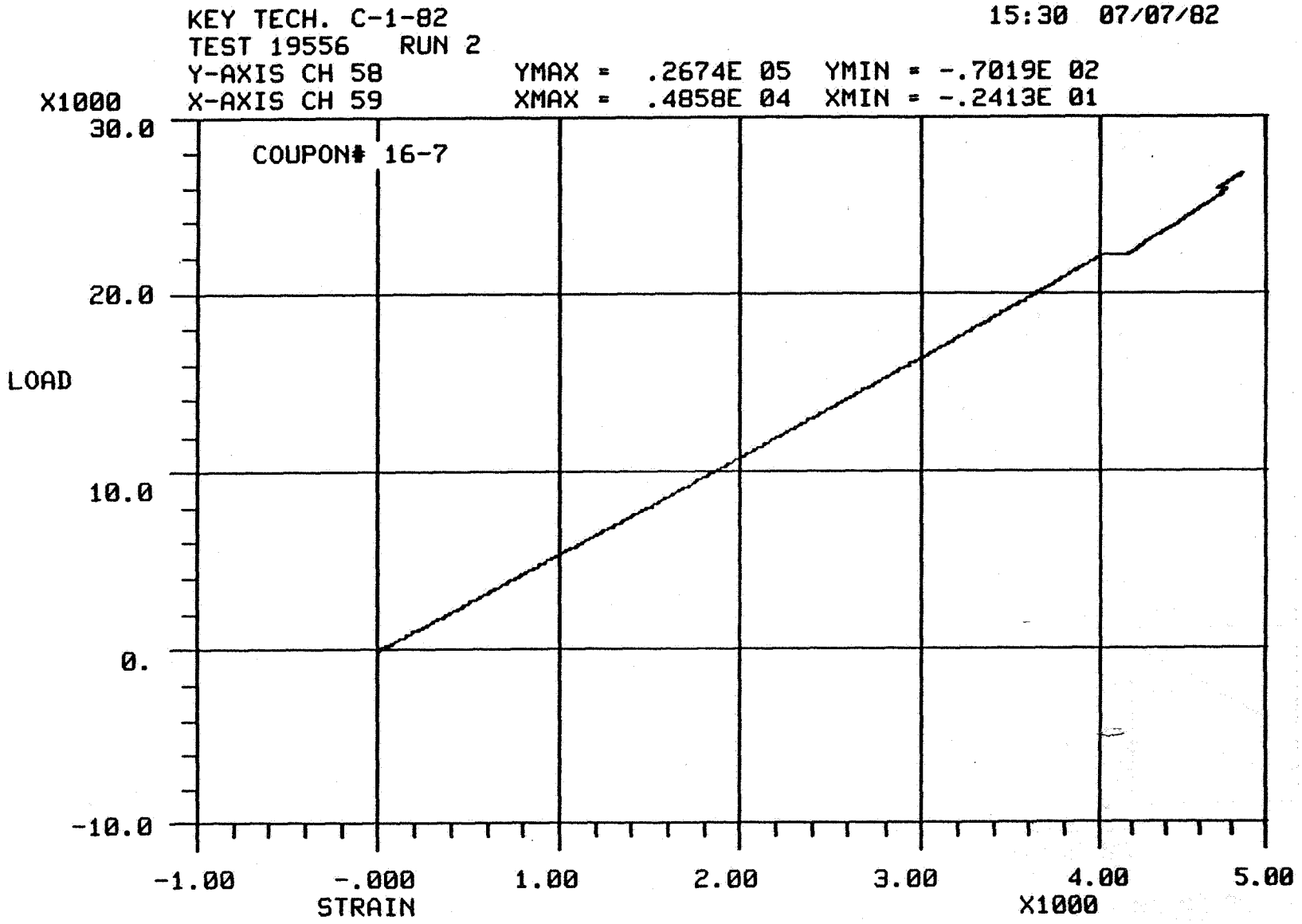

NASA KEY TECHNOLOGY TENSION TEST
11:10 07/16/82
TEST 19614 RUN 4
Y-AXIS CH 43
YMAX = .3148E 05
YMIN = -.2447E 02
X1000
X-AXIS CH 44
XMAX = .6171E 04
XMIN = .7940E 01
COUPON# 35-2
40.0
30.0
20.0
10.0
0.
-10.0
LOAD
0.
1.00
2.00
3.00
4.00
5.00
6.00
7.00
STRAIN
X1000

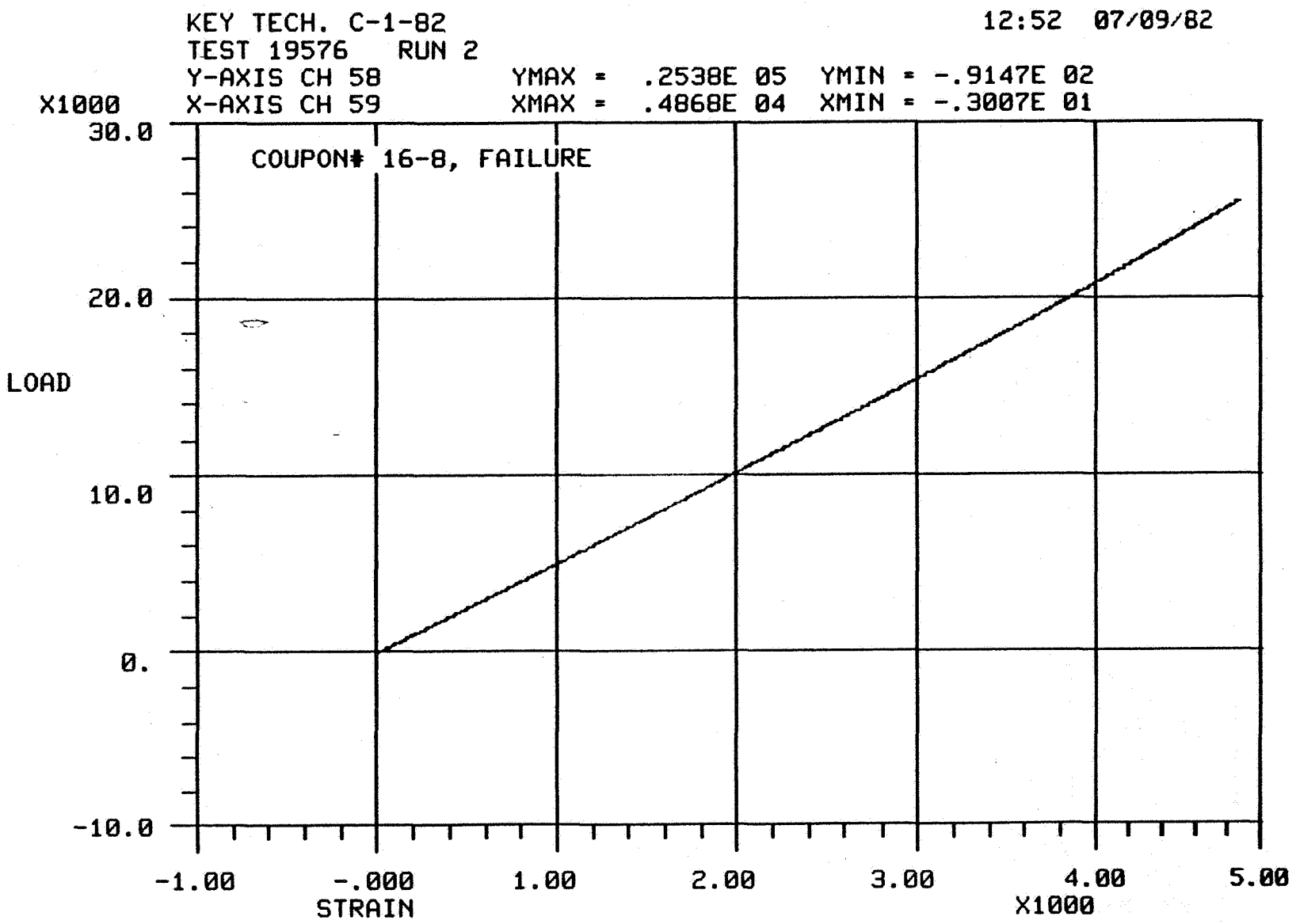

KEY TECH. C-1-82
13:41 07/09/82
TEST 19576 RUN 4
Y-AXIS CH 58
YMAX = .3143E 05
YMIN = .9766E 02
X-AXIS CH 59
XMAX = .6220E 04
XMIN = .9183E 01
X1000
40.0
COUPON# 15-7, FAILURE
30.0
LOAD
20.0
10.0
0.
0.
1.00
2.00
3.00
4.00
5.00
6.00
7.00
STRAIN
X1000


KEY TECH. C-1-82
14:27 07/09/82
TEST 19576 RUN 5
Y-AXIS CH 58 YMAX = .3228E 05 YMIN = .3360E 02
X-AXIS CH 59 XMAX = .6228E 04 XMIN = .7335E 01
X1000
COUPON# 15-8, FAILURE
LOAD
40.0
30.0
20.0
10.0
0.
0.
1.00
2.00
3.00
4.00
5.00
6.00
7.00
STRAIN
X1000

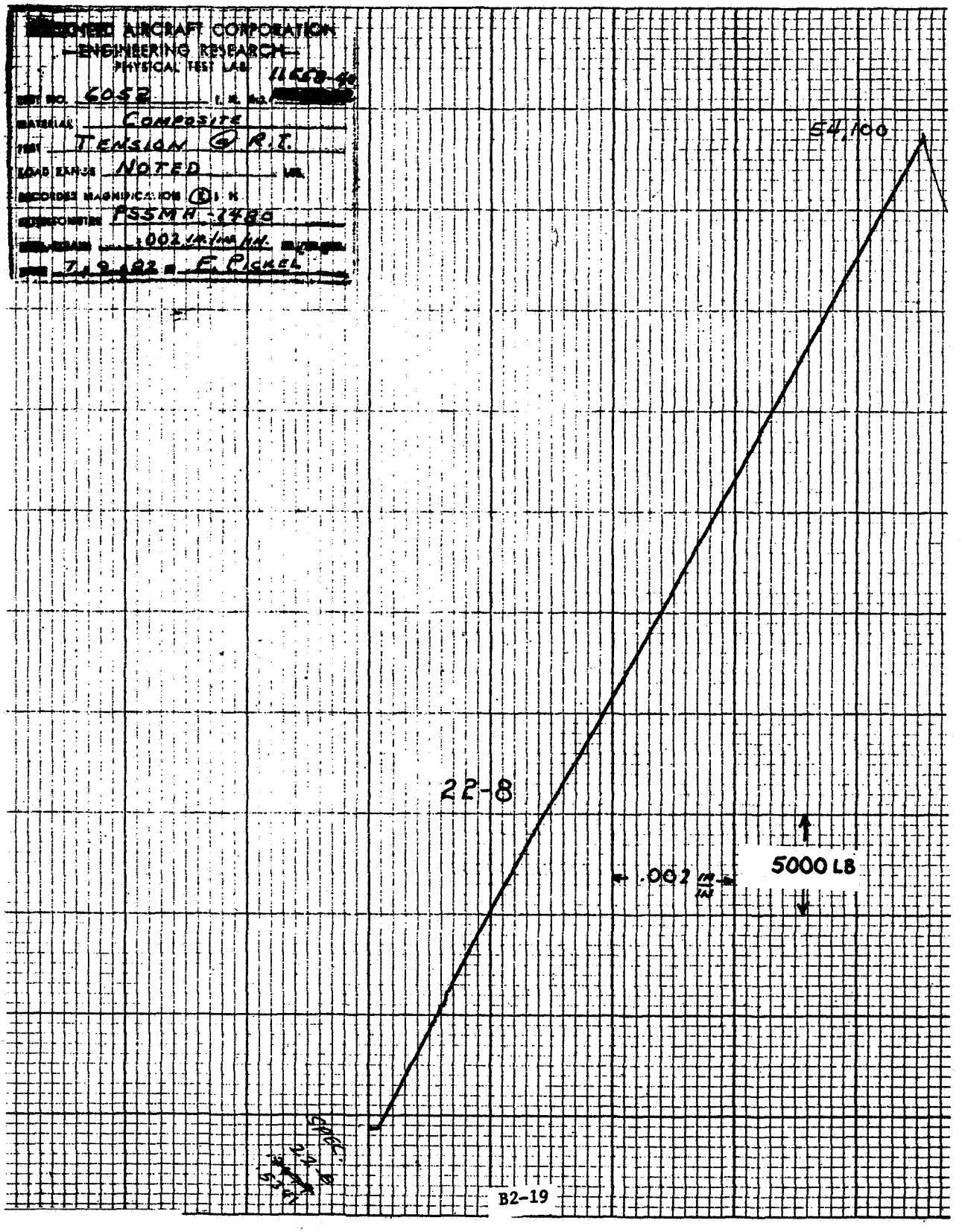

KEY TECH. C-1-82
14:39 07/09/82
TEST 19576 RUN 6
Y-AXIS CH 58
YMAX = .3279E 05
YMIN = -.1490E 02
X-AXIS CH 59
XMAX = .6086E 04
XMIN = .1249E 01
X1000
COUPON# 16-5, FAILURE
LOAD
40.0
30.0
20.0
10.0
0.
-10.0
0.
1.00
2.00
3.00
4.00
5.00
6.00
7.00
STRAIN
X1000


KEY TECK. C-1-82
14:39 07/07/82
TEST 19553 RUN 2
Y-AXIS CH 58
YMAX = .2490E 05
YMIN = -.3812E 02
X1000
X-AXIS CH 59
XMAX = .4992E 04
XMIN = -.1215E 01
COUPON# 16-6
25.0
20.0
15.0
LOAD
10.0
5.00
0.
-5.00
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
STRAIN
X1000

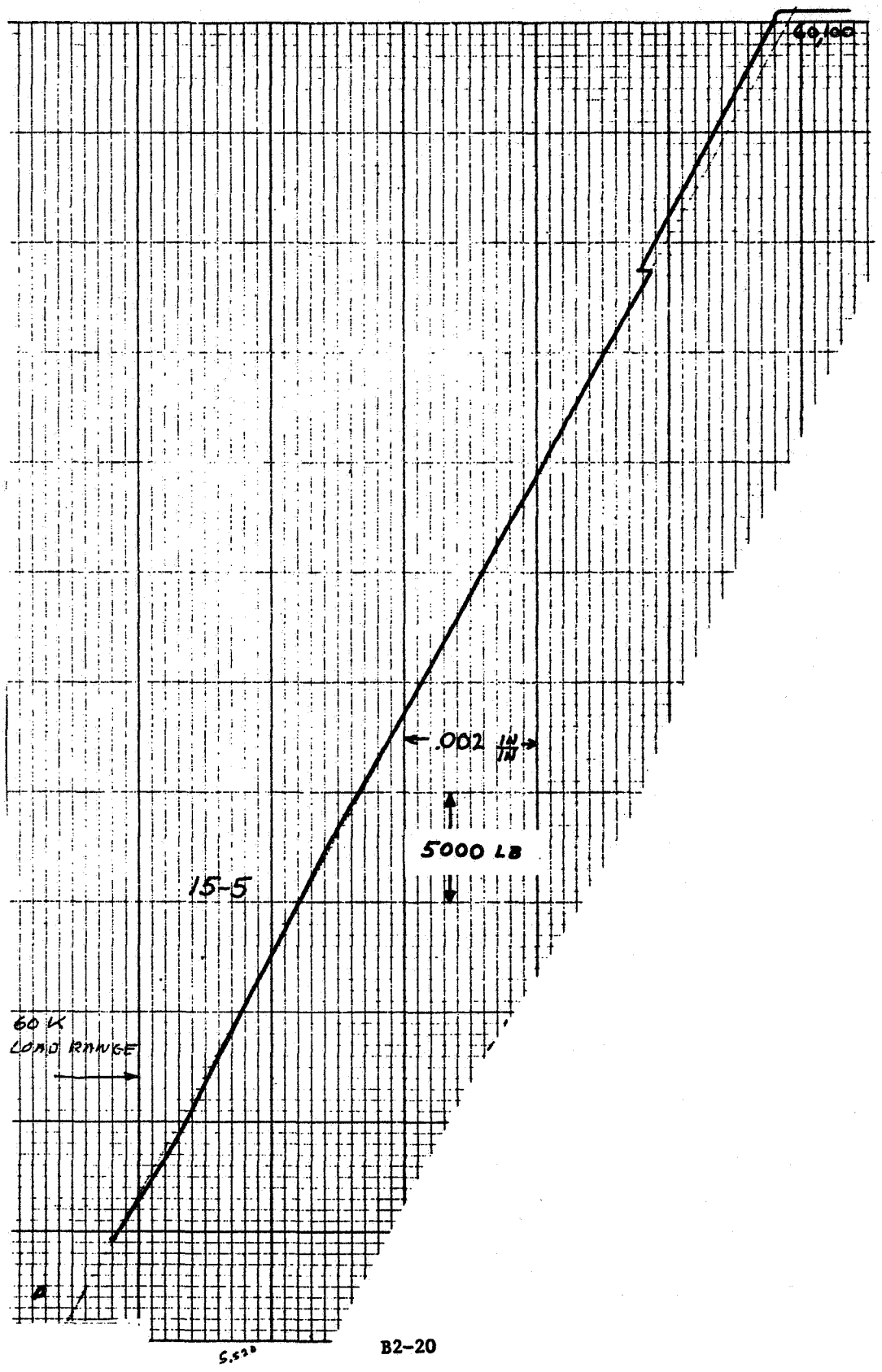

KEY TECH. C-1-82
TEST 19556 RUN 2
Y-AXIS CH 58
X-AXIS CH 59
YMAX = .2674E 05
XMAX = .4858E 04
YMIN = -.7019E 02
XMIN = -.2413E 01
15:30 07/07/82
X1000
30.0
20.0
10.0
0.
-10.0
LOAD
COUPON# 16-7
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
STRAIN
X1000


KEY TECH. C-1-82
TEST 19576 RUN 2
12:52 07/09/82
Y-AXIS CH 58
YMAX = .2538E 05
YMIN = -.9147E 02
X1000
X-AXIS CH 59
XMAX = .4868E 04
XMIN = -.3007E 01
30.0
COUPON# 16-8, FAILURE
20.0
LOAD
10.0
0.
-10.0
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
STRAIN
X1000

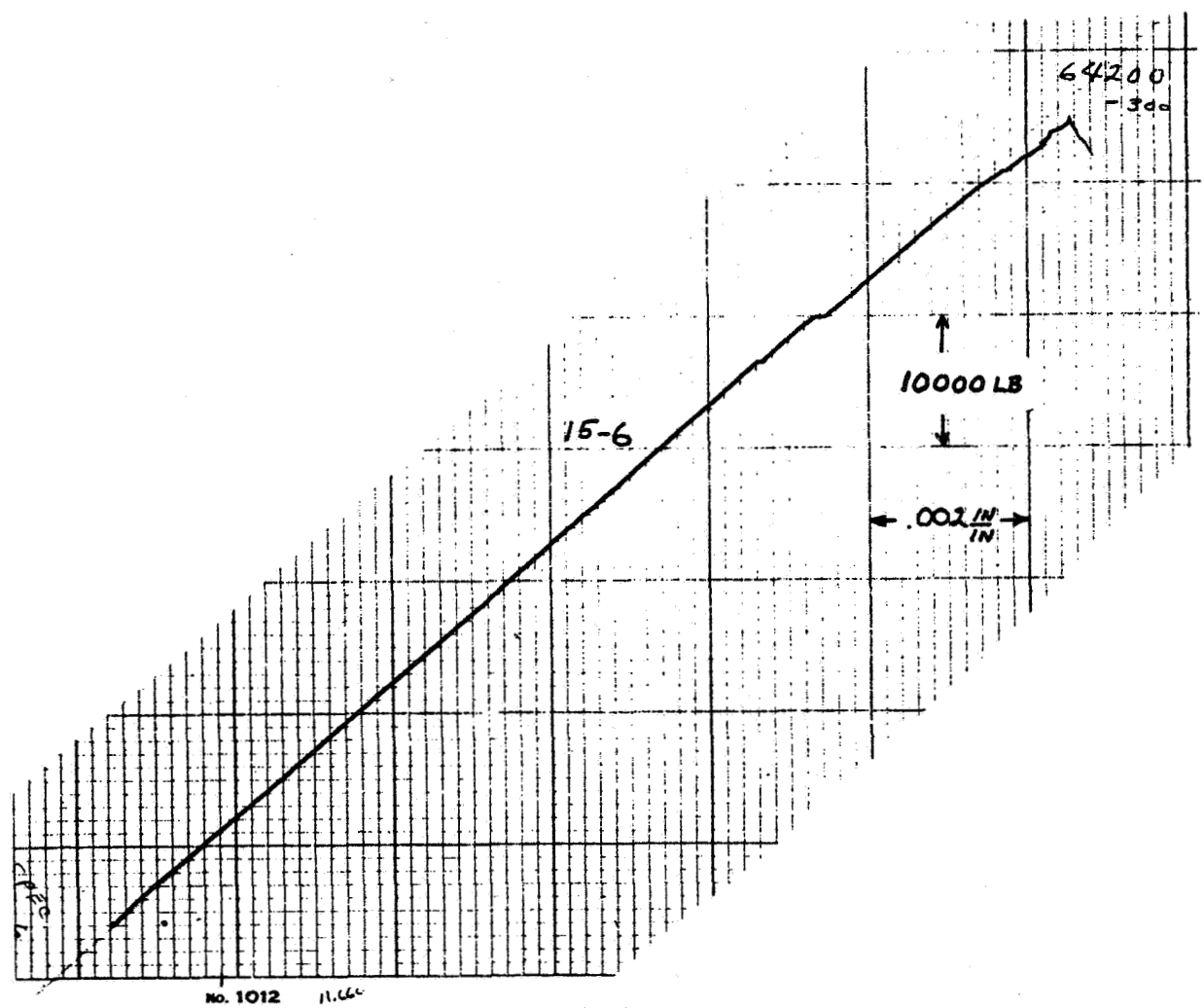
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OF POOR QUALITY

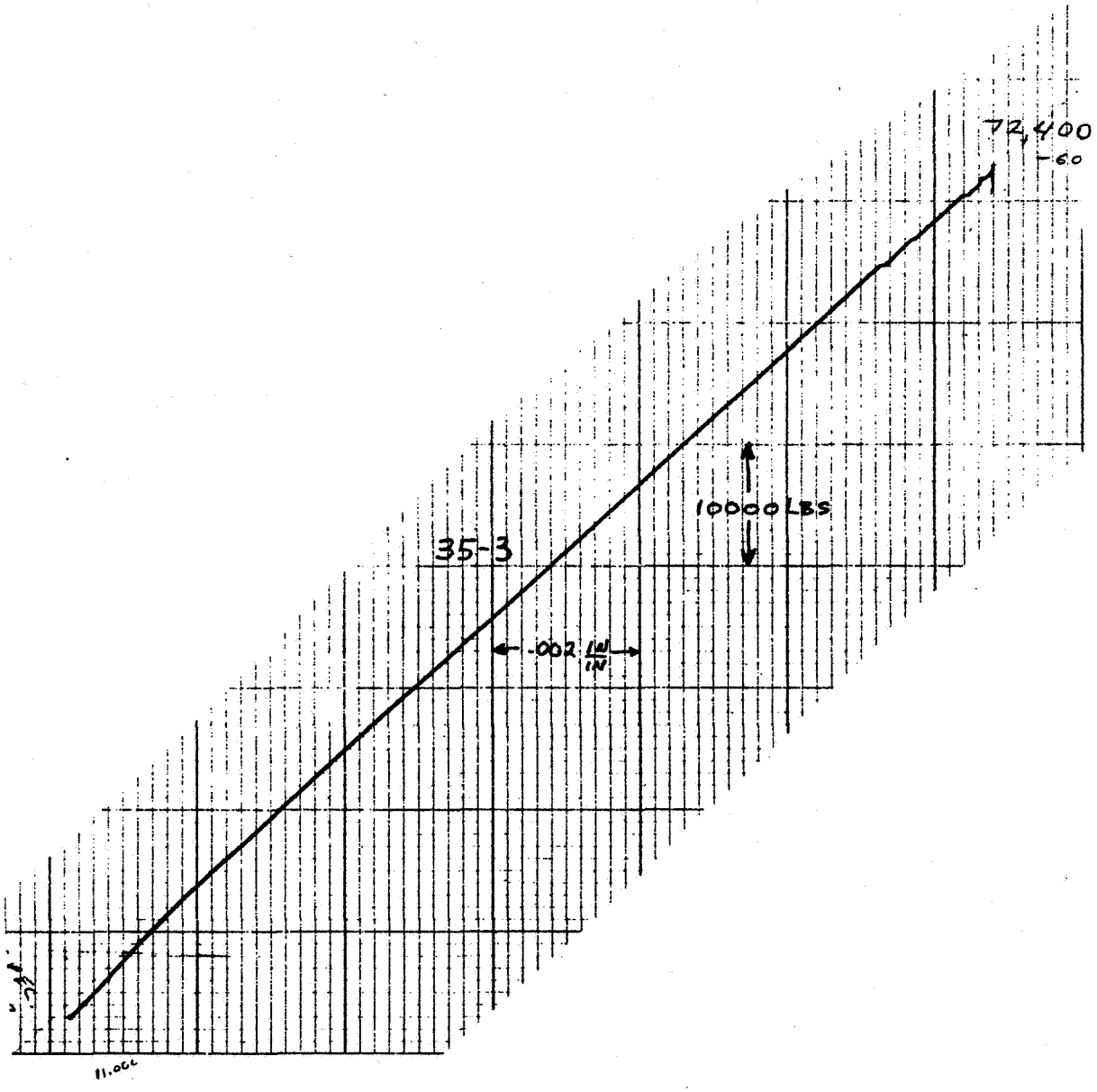


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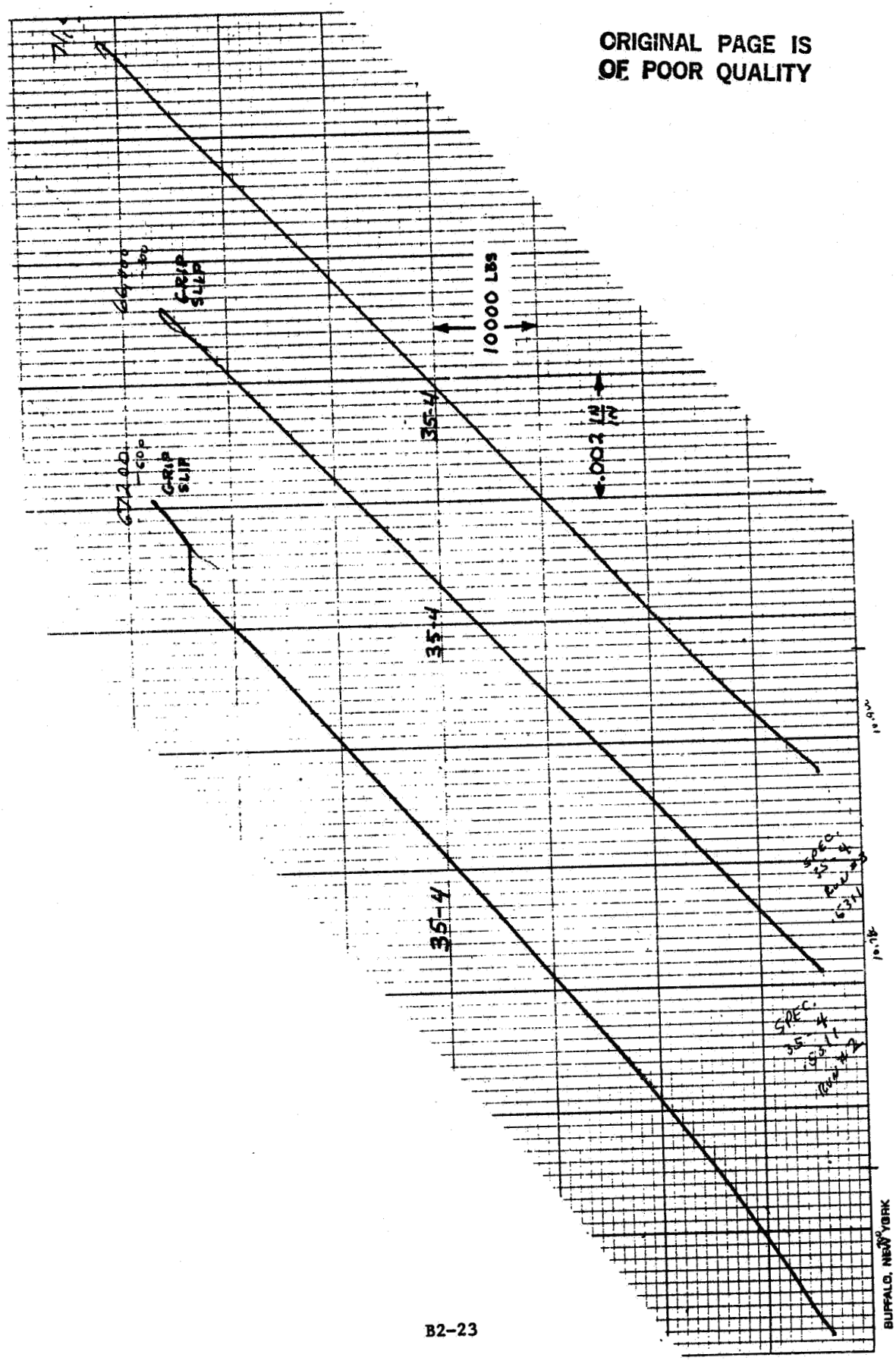


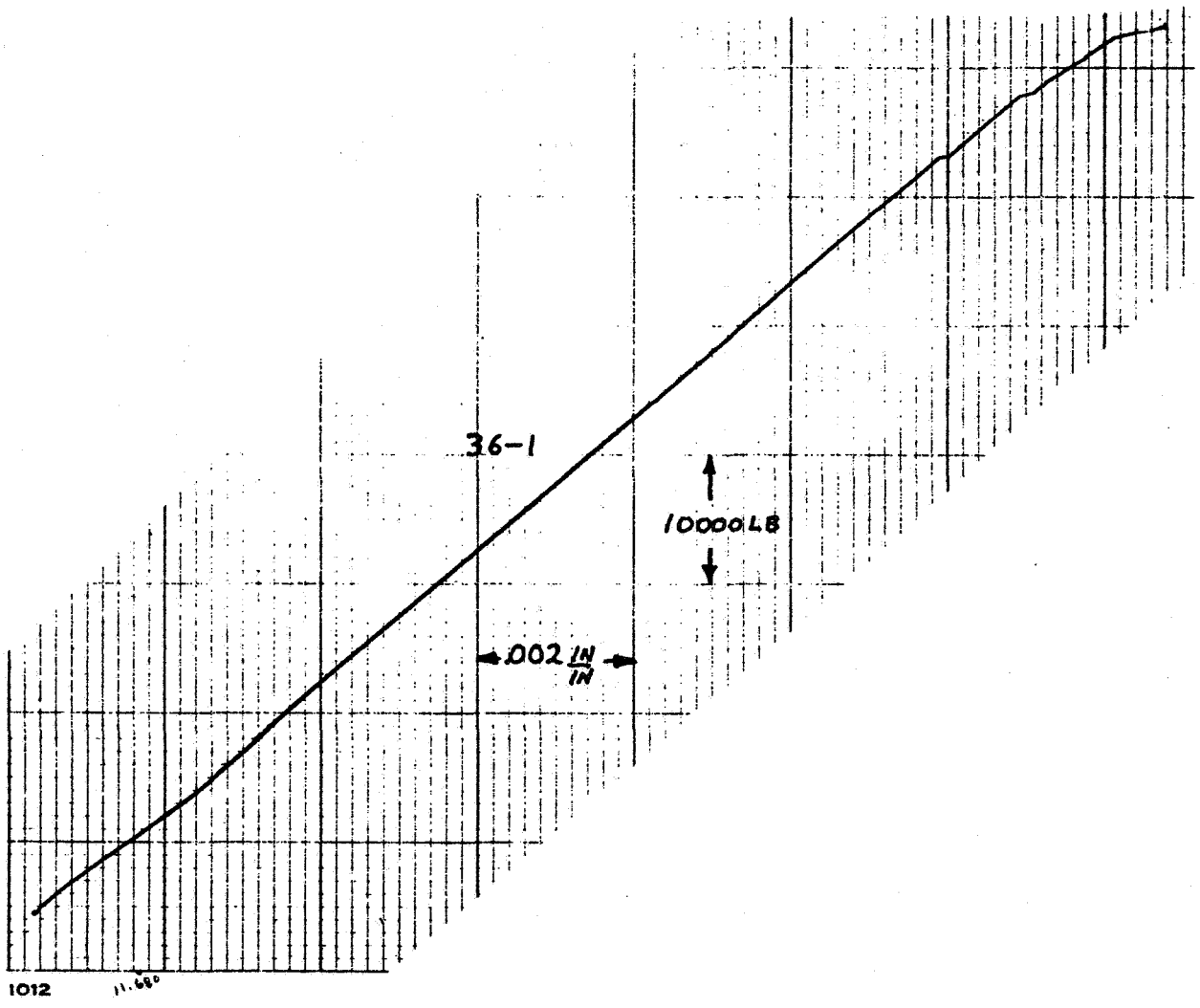
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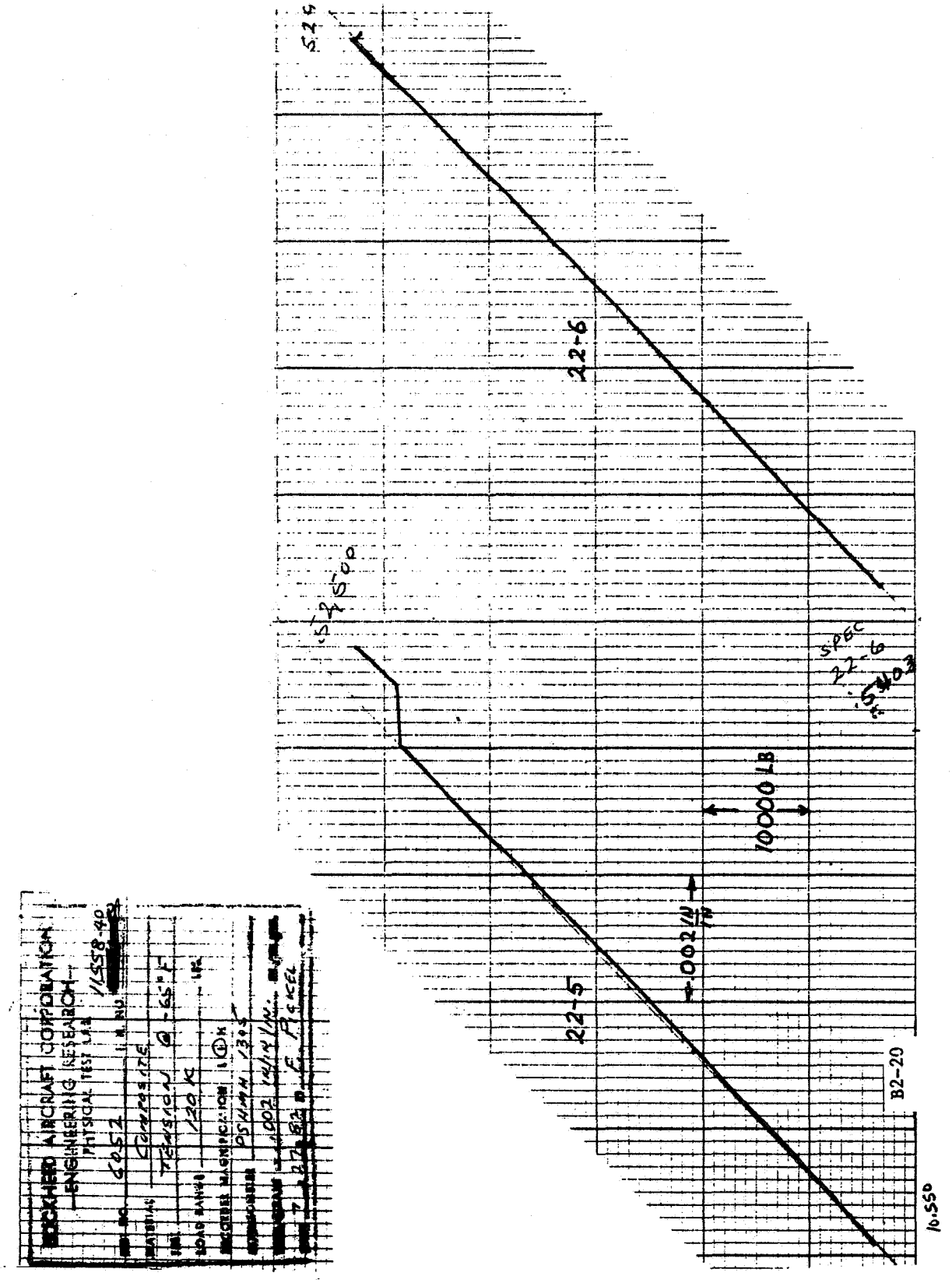

72,400
60
10000 LBS
35-3
.002 LBS/IN
11.000

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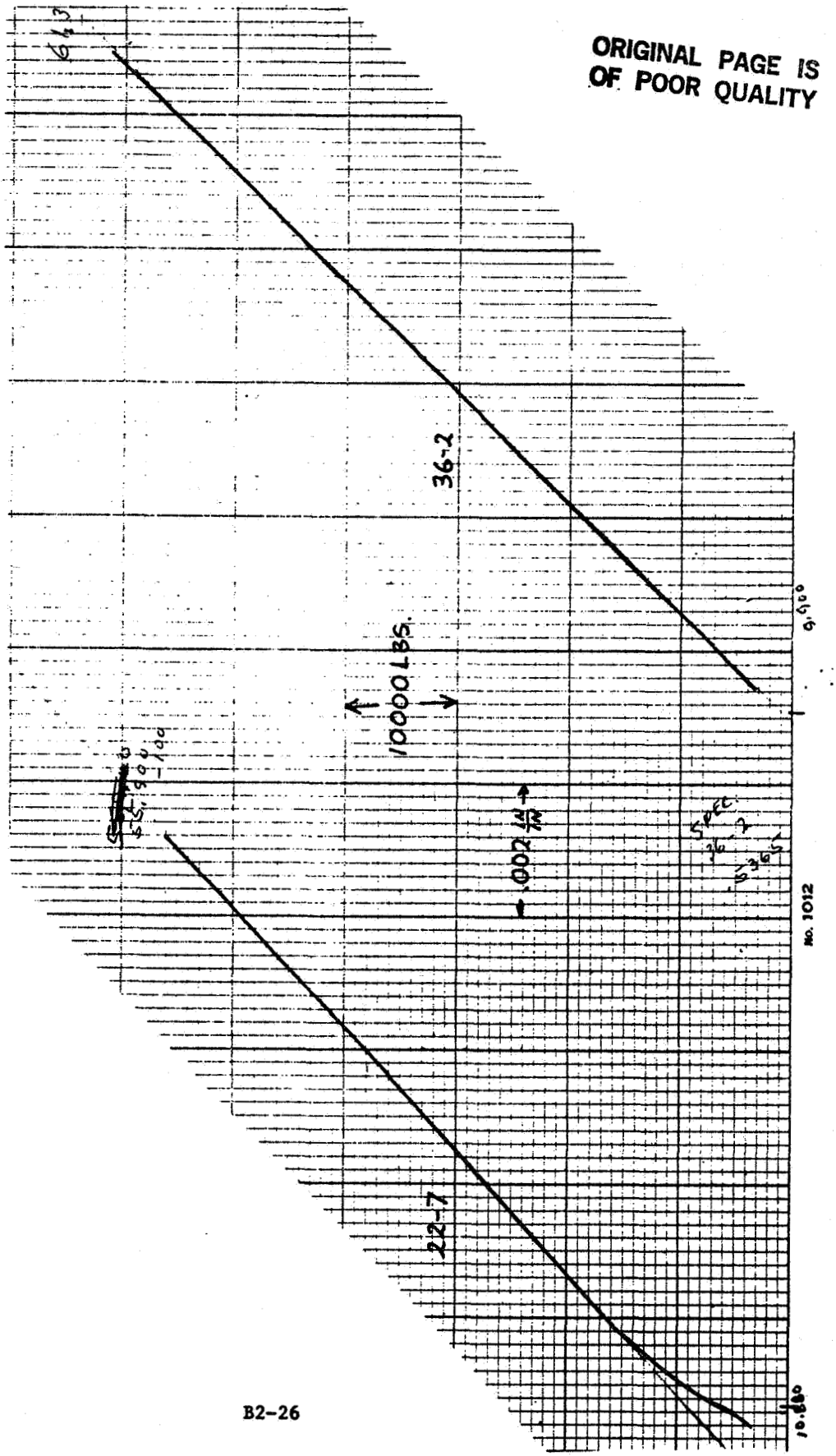



36-1
10000LB
.002 IN/IN
1012
11.68°

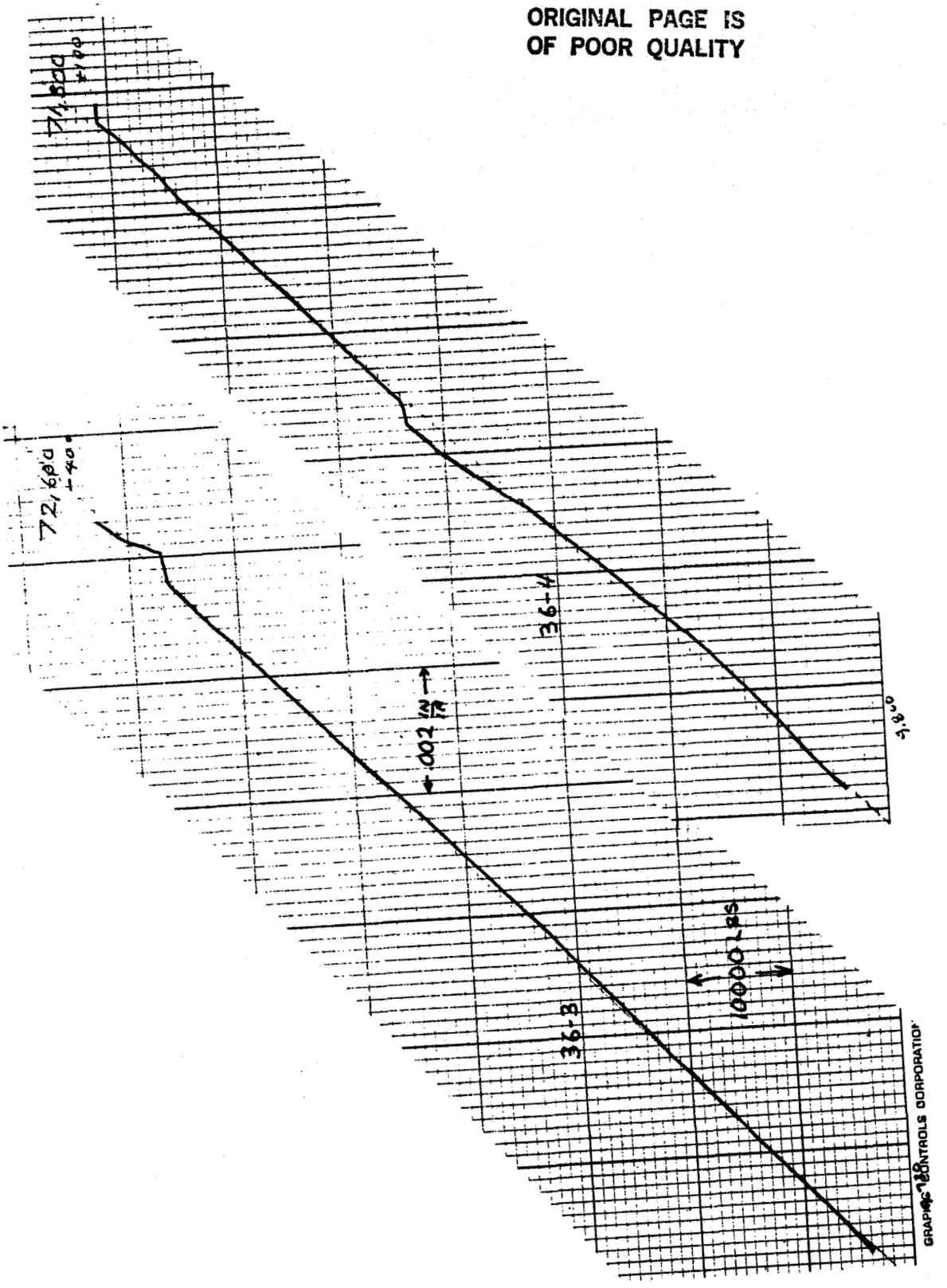
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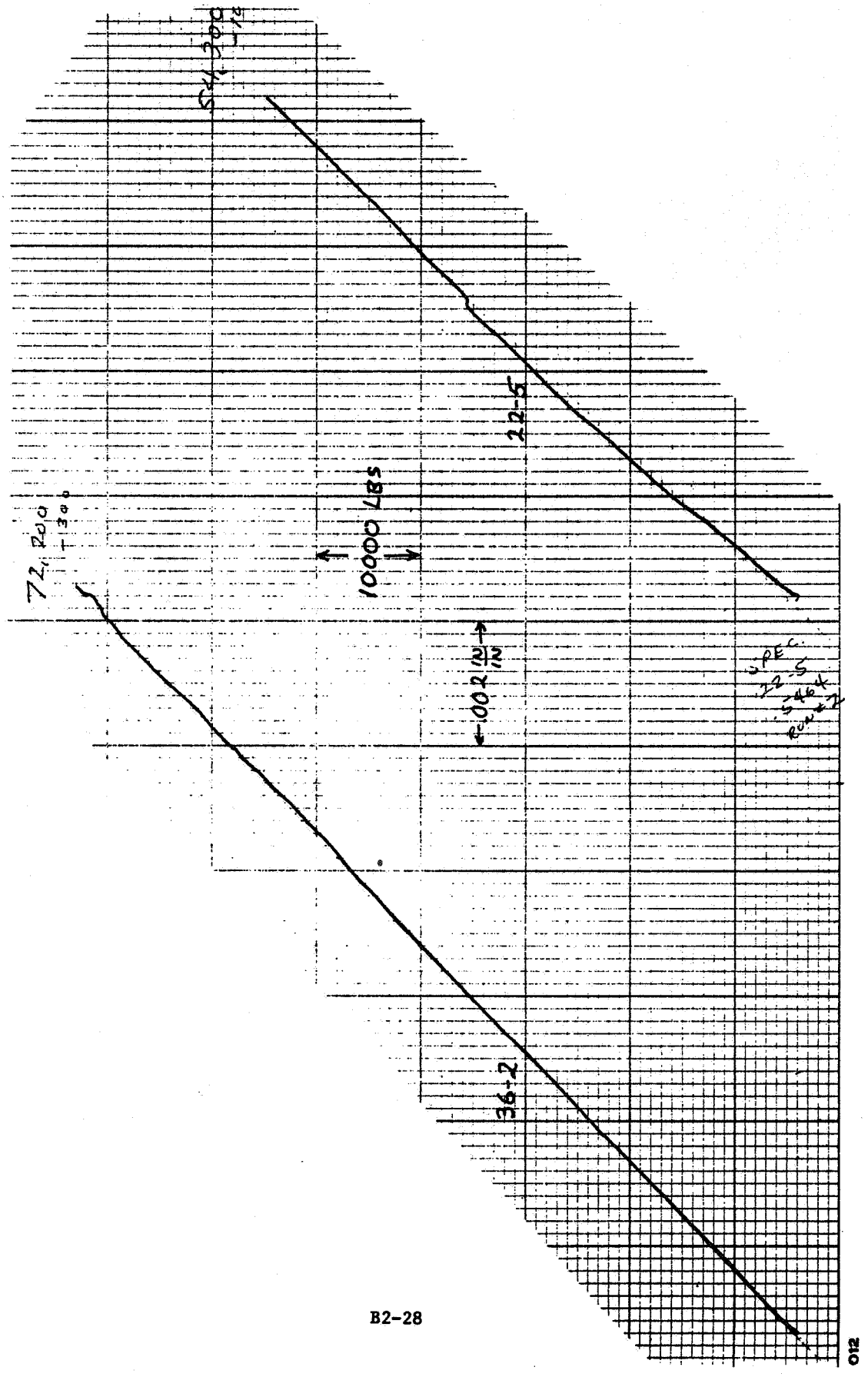


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54,300
72,200
10000 LBS
22-5
36-2
012

APPENDIX B3

TO. P. SANDIFER	DATE 11	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11268-30
FROM T. GILLETTE	10	SUBJECT 180°F COMPRESSION KEY TECHNOLOGY	REF
MODEL	82		A O FWA

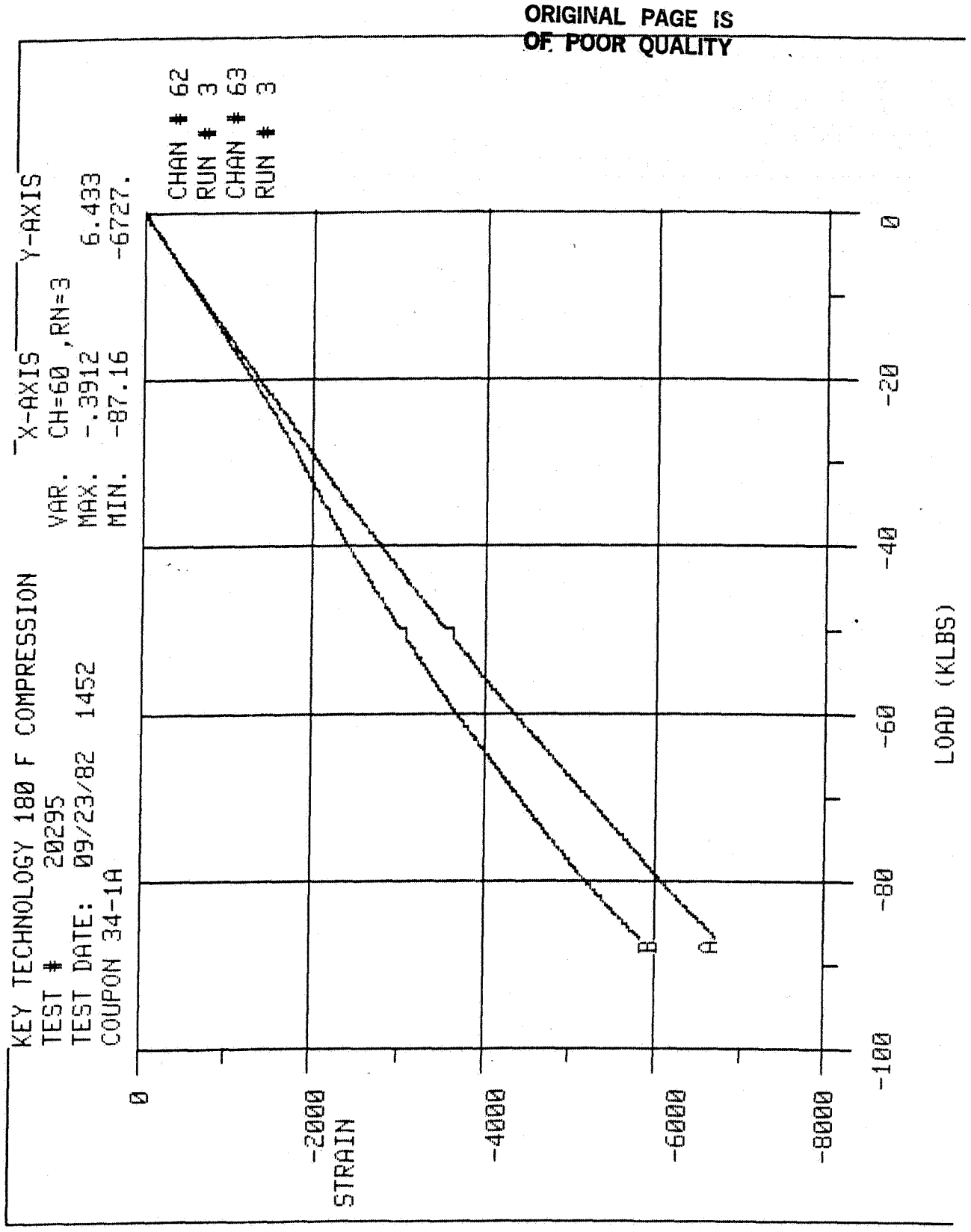
CONTINUED FROM E N #

COUPON ID	CONDITION	THICKNESS END	THICKNESS CENTER	THICKNESS END	WIDTH	AREA IN²
34-1A	180°F WET	.2683	.2693	.2740	5.004 5.004	1.354
34-1B	↓	.2690	.2681	.2685	5.005 5.004	1.344
*34-2A		.2722	.2685	.2687	5.003 5.003	1.349

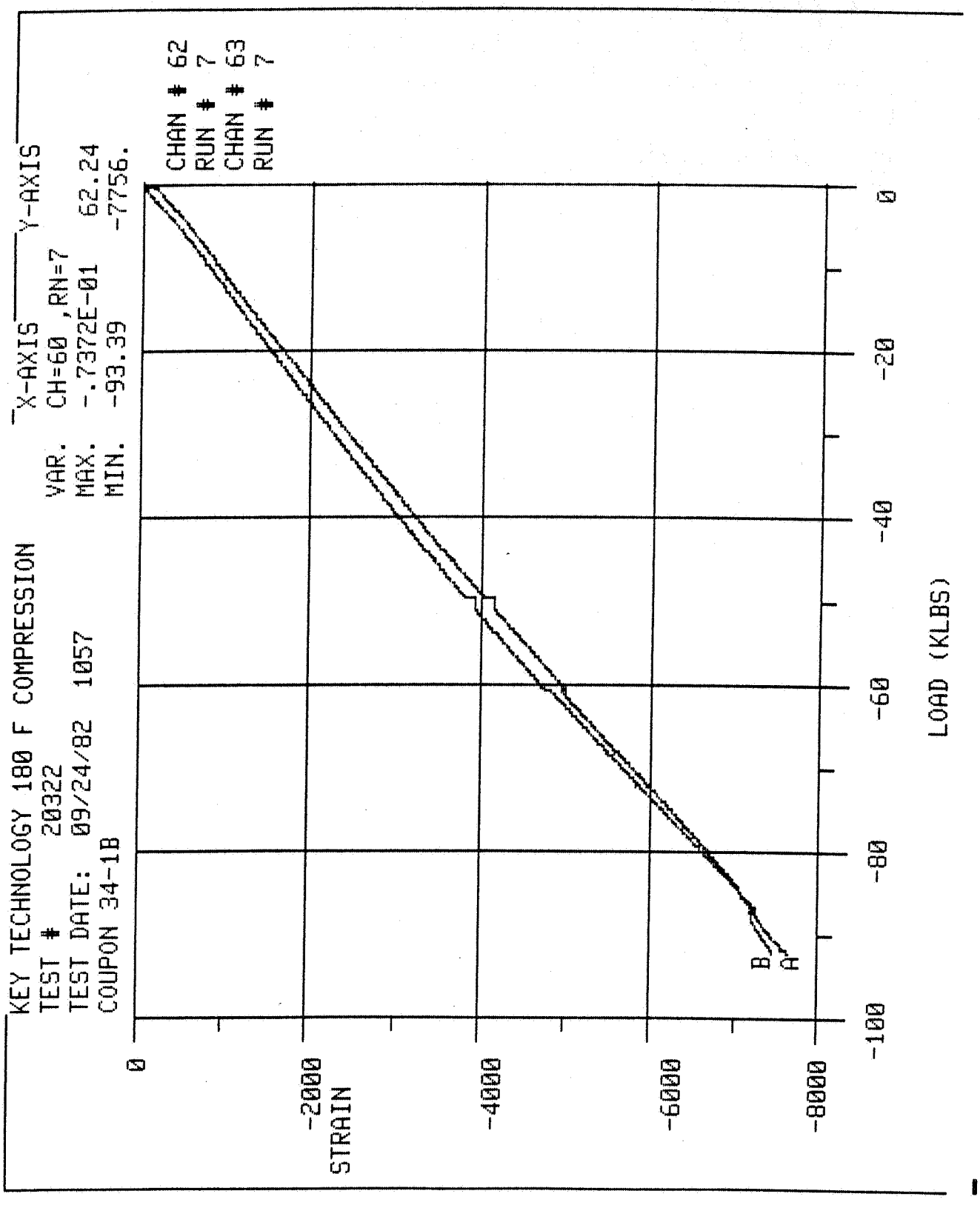
COUPON ID	AREA IN²	FAILURE LOAD (LBS)	FAILURE STRESS (KSI)	STRAINS MICRO IN/IN NO1 (A)	STRAINS MICRO IN/IN NO2 (B)
34-1A	1.354	-87.16	-64.37	-6725	-5840
34-1B	1.344	-93.39	-69.48		-7755
*34-2A	1.349	-49.440	-36.65		

* DATA NOT VIABLE
SPECIMEN WAS TOO SHORT FOR USUALL INSTALLATION IN FIXTURE. SPACER BAR .250" THICK WAS PLACED ON EITHER END OF COUPON TO PROVIDE PROPER LENGTH FOR FIXTURE.

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TO P. SANDIFER | DATE 8

FROM T. GILETTE | 9

MODEL | 82

LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED CORPORATION
ENGINEERS NOTEBOOK

Nº 11268-14

SUBJECT KEY TECHNOLOGY COMPRESSION TEST RT PANEL 35

REF

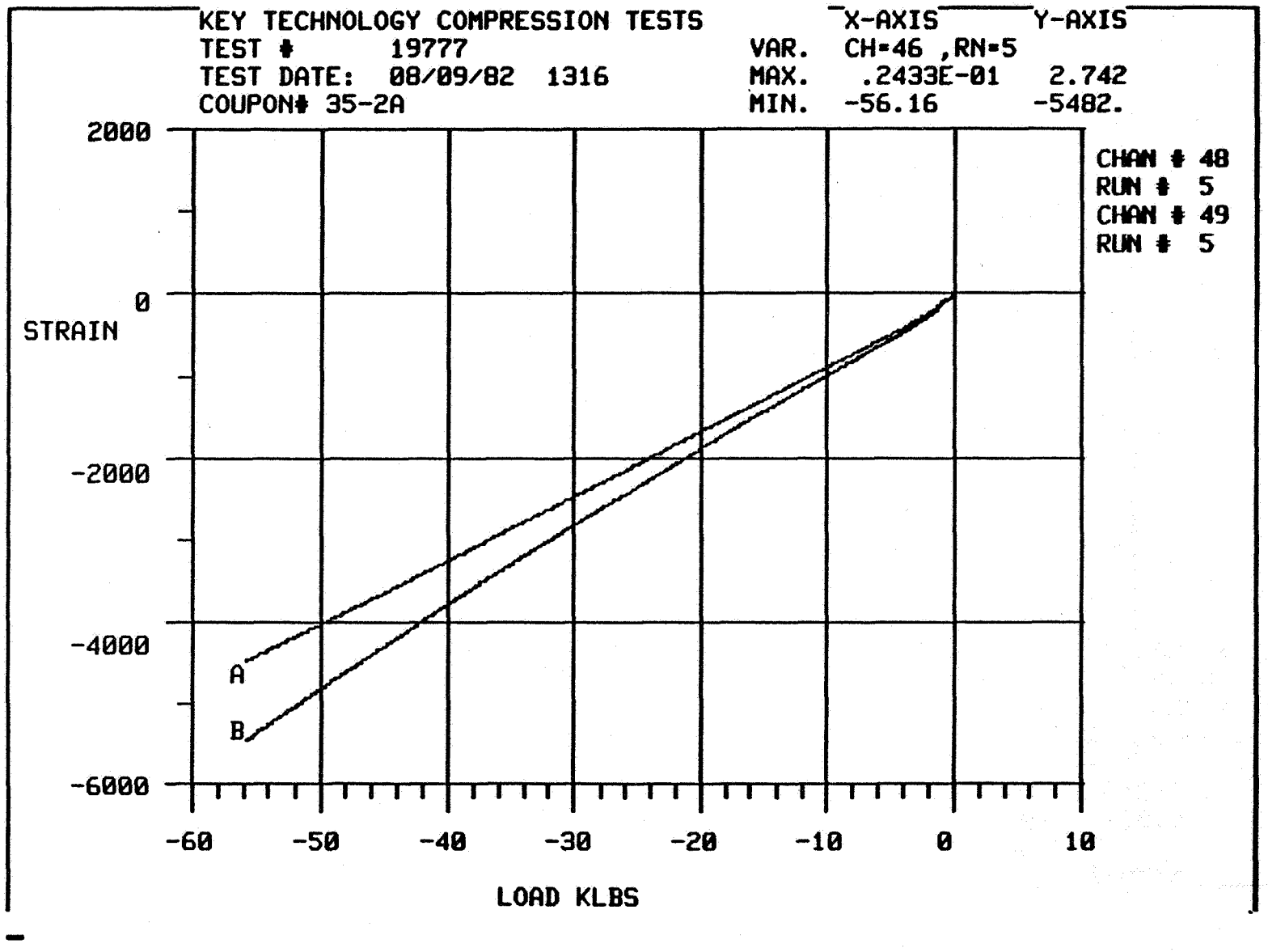
W.O. EWA

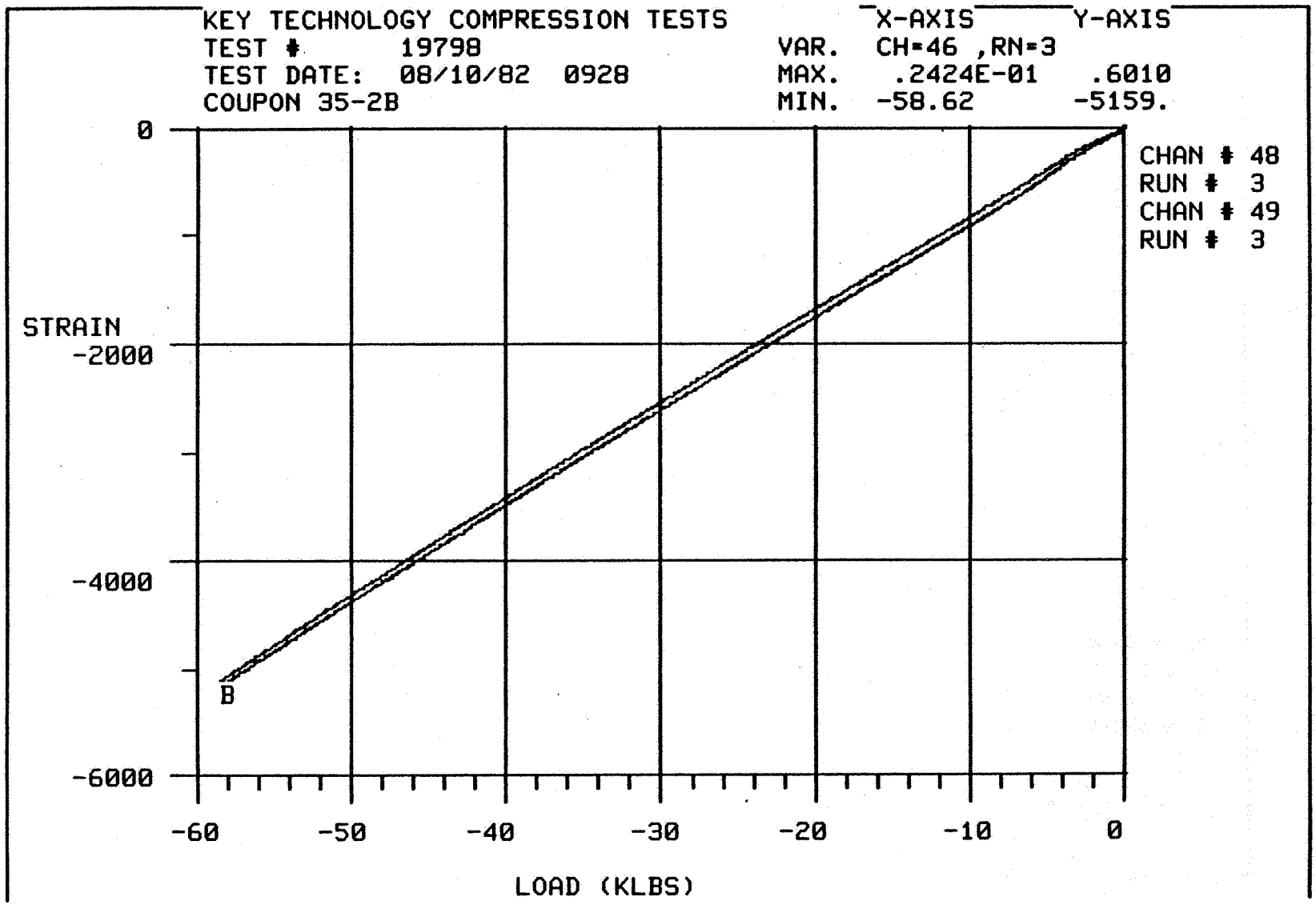
COUPON ID #	CONDITION	THICKNESS END	THICKNESS CENTER	THICKNESS END	WIDTH	AREA (IN)^2
35-2A	IMACTED	.2600	.2765	.2695	5.006, 5.007	1.345
35-2B		.2710	.2703	.2714	5.006, 5.007	1.356
35-3A		.2765	.2745	.2749	5.008, 5.008	1.379
35-3B		.2705	.2705	.2780	5.007, 5.008	1.367
35-4A		.2775	.2750	.2738	5.008, 5.007	1.379
35-4B		.2798	.2748	.2725	5.009, 5.009	1.381

COUPON ID #	FAILURE LOAD (KIPS)	GROSS STRESS (KSI)	STRAIN GAGE 1	STRAIN GAGE 2
35-2A	-56.16	-41.75	-4501	-5482
35-2B	-58.62	-43.23	-5116	-5159
35-3A	-52.05	-37.74	-4435	-4570
35-3B	-41.63	-30.45	-3628	-3578
35-4A	-42.28	-30.66	-3784	-3765
35-4B	-46.23	-33.47	-4094	-4101

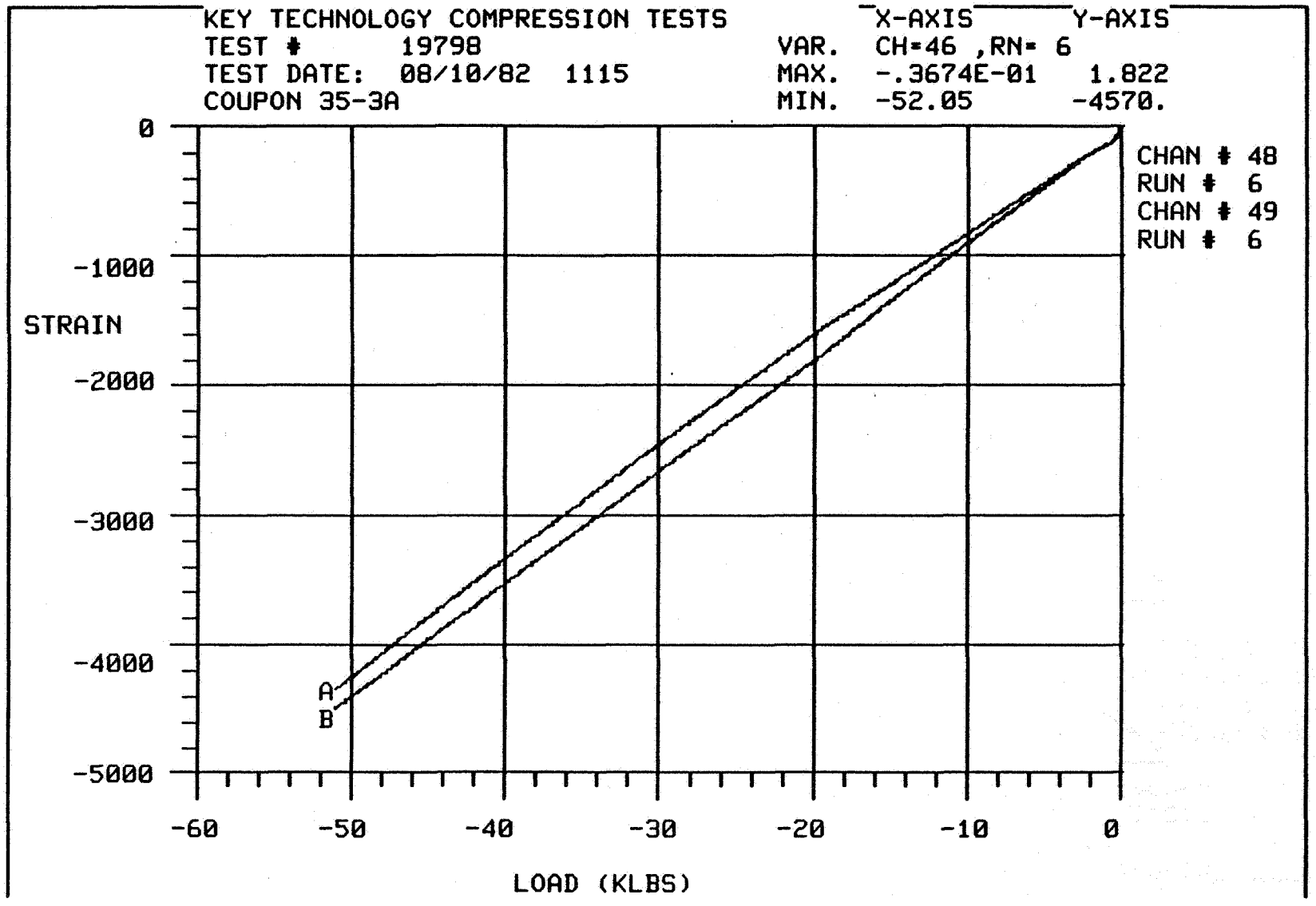
GAGE 1 IS ON IMPACTED SIDE

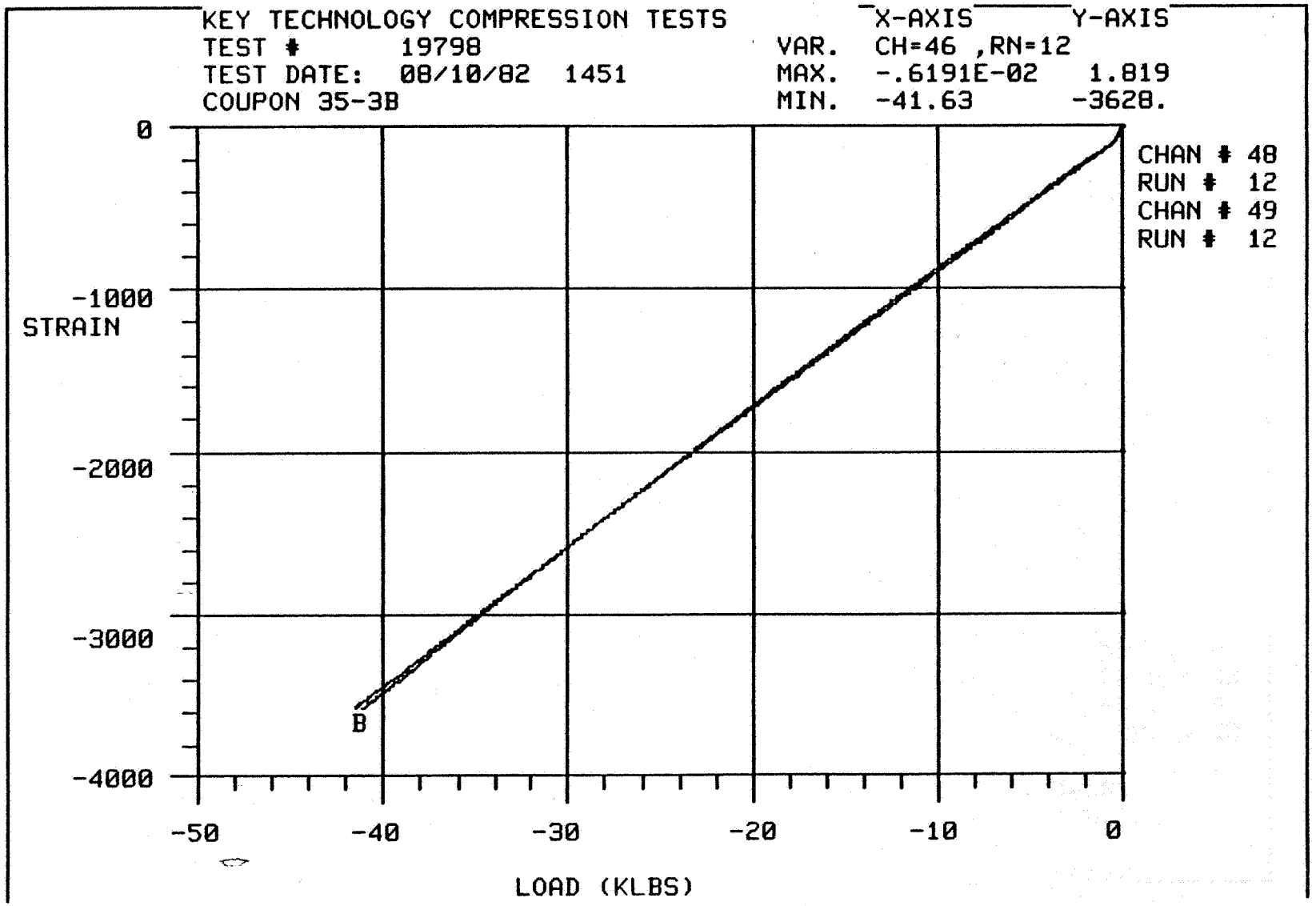
R_{CAL} FOR 10.012 KΩ IS 5674

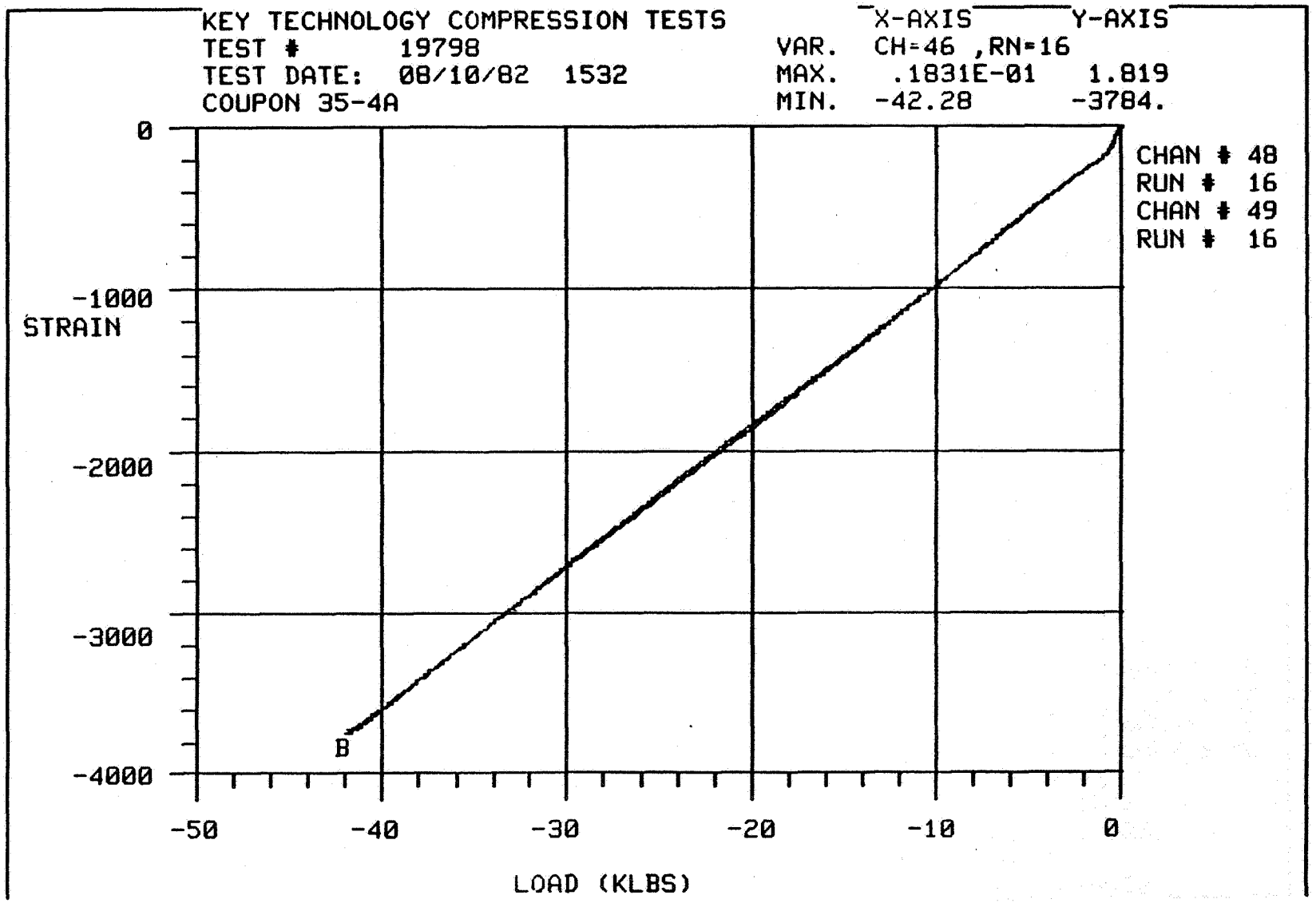

KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19777
TEST DATE: 08/09/82 1316
COUPON# 35-2A
X-AXIS
Y-AXIS
VAR. CH=46 ,RN=5
MAX. .2433E-01 2.742
MIN. -56.16 -5482.
CHAN # 48
RUN # 5
CHAN # 49
RUN # 5
2000
0
-2000
-4000
-6000
STRAIN
A
B
-60
-50
-40
-30
-20
-10
0
10
LOAD KLBS

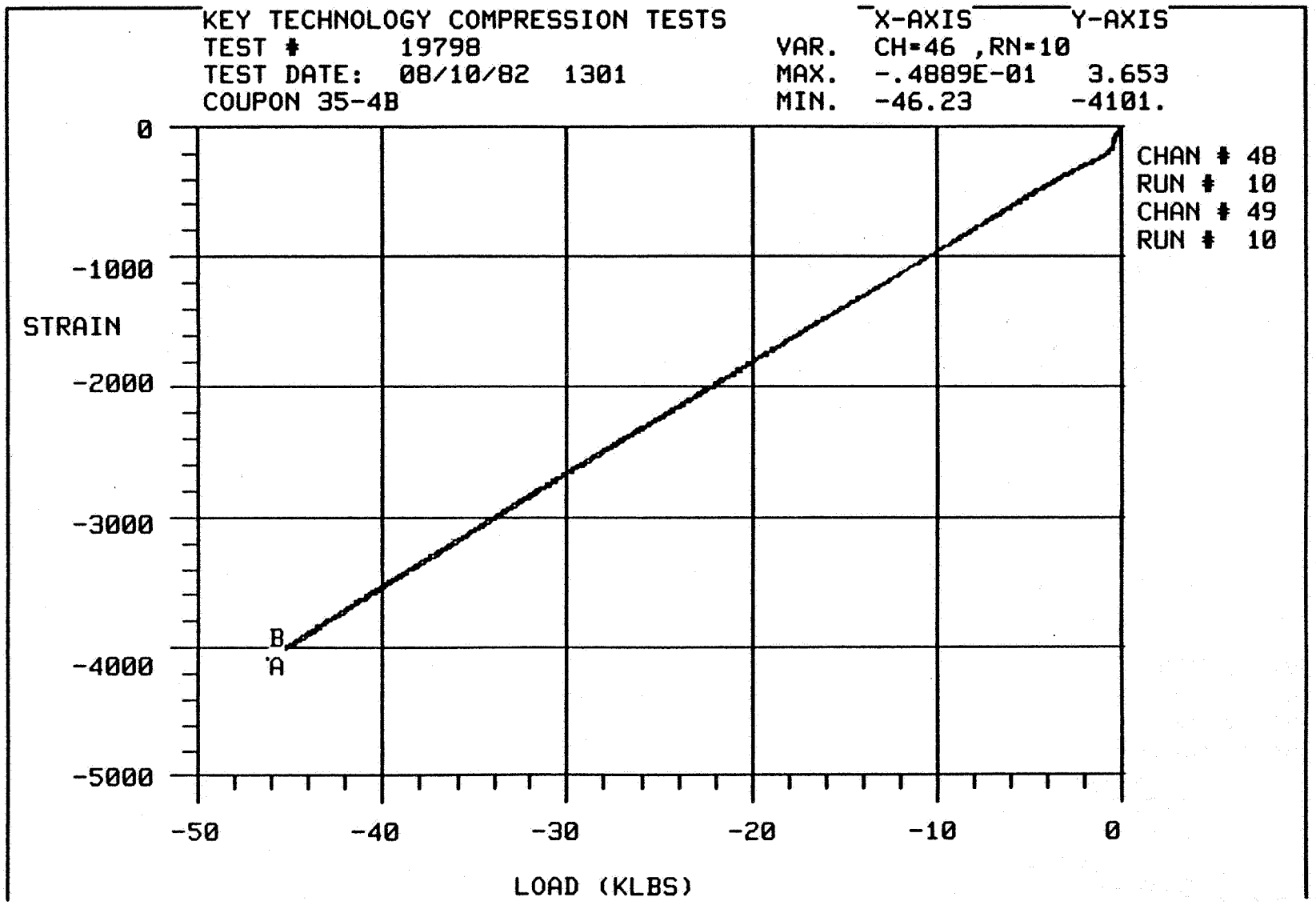

KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19798
TEST DATE: 08/10/82 0928
COUPON 35-2B
X-AXIS
Y-AXIS
VAR. CH=46 ,RN=3
MAX. .2424E-01 .6010
MIN. -58.62 -5159.
CHAN # 48
RUN # 3
CHAN # 49
RUN # 3
STRAIN
0
-2000
-4000
-6000
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)
B

4 - C - 4


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19798
TEST DATE: 08/10/82 1115
COUPON 35-3A
X-AXIS Y-AXIS
VAR. CH=46 ,RN= 6
MAX. -.3674E-01 1.822
MIN. -52.05 -4570.
CHAN # 48
RUN # 6
CHAN # 49
RUN # 6
0
-1000
-2000
-3000
-4000
-5000
STRAIN
A
B
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19798
TEST DATE: 08/10/82 1451
COUPON 35-3B
X-AXIS Y-AXIS
VAR. CH=46 ,RN=12
MAX. -.6191E-02 1.819
MIN. -41.63 -3628.
CHAN # 48
RUN # 12
CHAN # 49
RUN # 12
0
-1000
-2000
-3000
-4000
STRAIN
B
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19798
TEST DATE: 08/10/82 1532
COUPON 35-4A
X-AXIS Y-AXIS
VAR. CH=46 ,RN=16
MAX. .1831E-01 1.819
MIN. -42.28 -3784.
CHAN # 48
RUN # 16
CHAN # 49
RUN # 16
0
-1000
-2000
-3000
-4000
STRAIN
B
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19798
TEST DATE: 08/10/82 1301
COUPON 35-4B
X-AXIS Y-AXIS
VAR. CH=46 ,RN=10
MAX. -.4889E-01 3.653
MIN. -46.23 -4101.
CHAN # 48
RUN # 10
CHAN # 49
RUN # 10
0
-1000
-2000
-3000
-4000
-5000
STRAIN
B
A
-50
-40
-30
-20
-10
0
LOAD (KLBS)

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TO P SANDIFER	DATE 7	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11268-12
FROM T. GILLETTE	29	SUBJECT KEY TECHNOLOGY 3.5" COMPRESSION UNNOTCHED	REF:
MODEL	82		N/A

CONTINUED FROM E.N. #

COUPON ID	THICKNESS			WIDTH
34-2B	.2689	.2675	.2710	3.500, 3.500
34-3B	.2706	.2709	.2706	3.500, 3.501
34-3A	.2736	.2710	.2703	3.501, 3.501

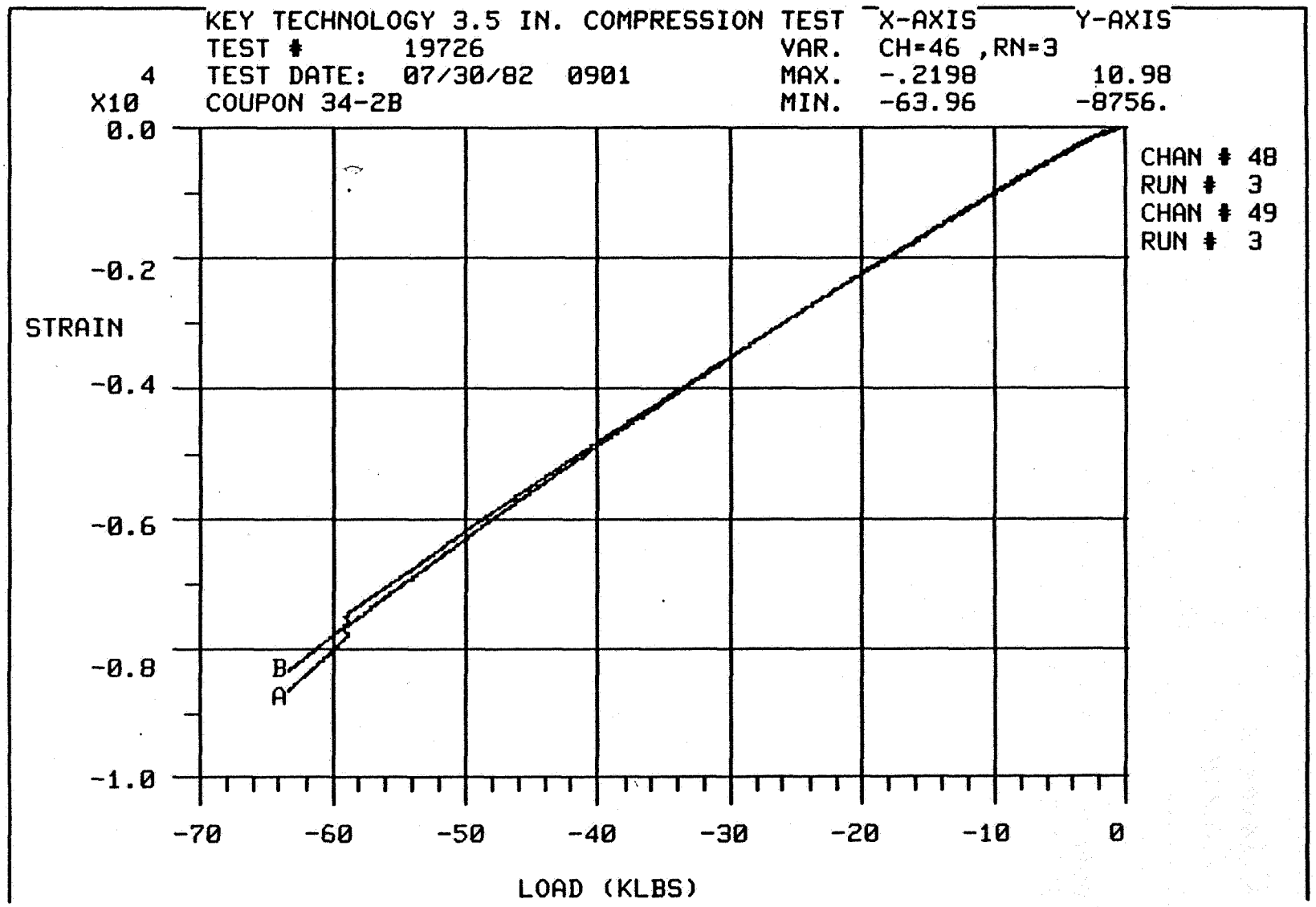
COUPON ID #	FAILURE LOAD LBS	GROSS STRESS (KSI)	STRAIN NO1(A)	STRAIN NO2(B)	REMARKS
34-2B	-63.96	-67.90	-8756	-8423	TEST RUN WITH 3.0" PLATES
34-3B	-63.44	-66.95	-8400	-8508	TEST RUN WITH 3.5" PLATES
34-3A	-63.59	-66.87	-8046	-9372	

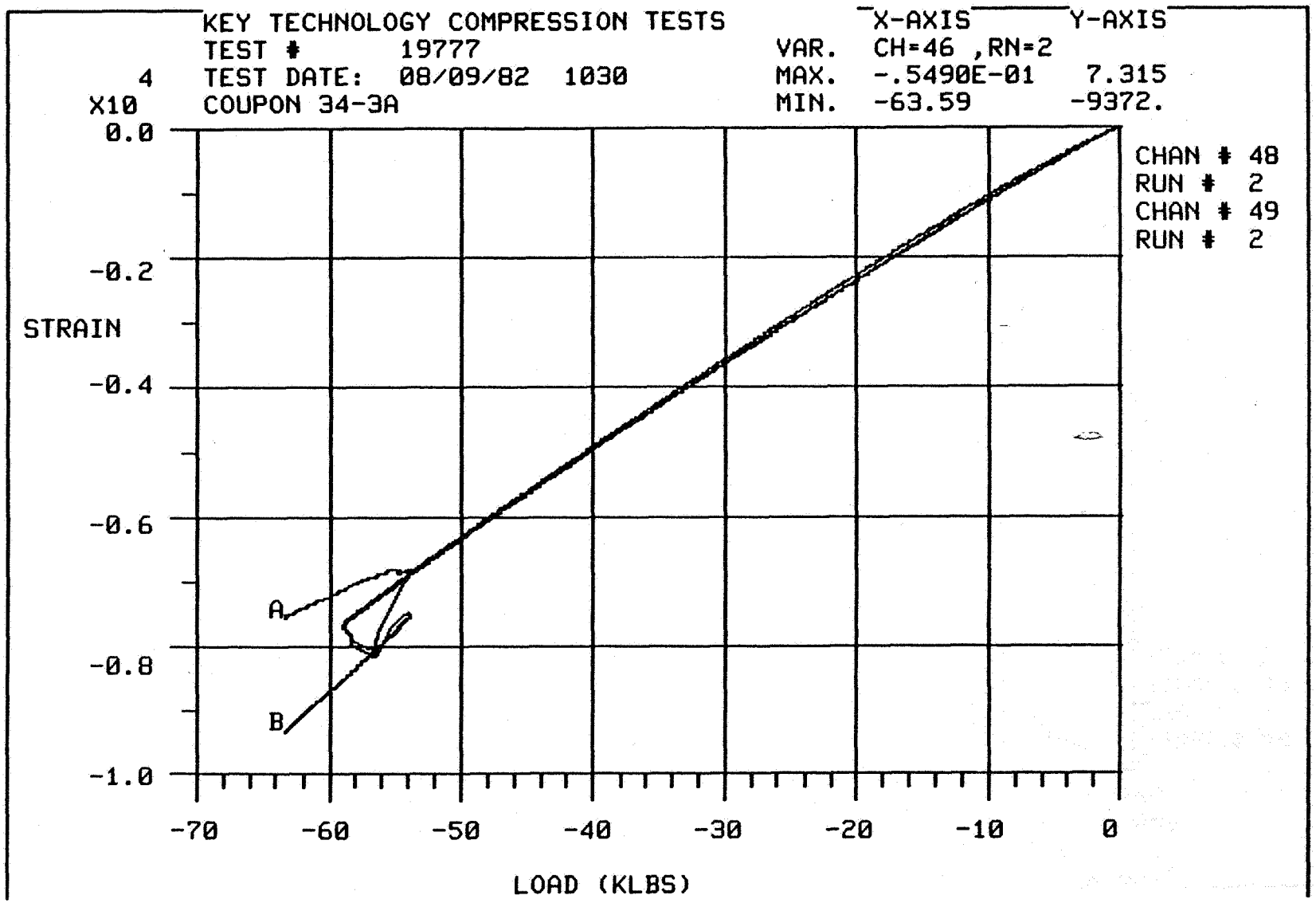
34-2B FAILED AT TOP WHILE 34-2B & 34-2A FAILED AT BOTTOM

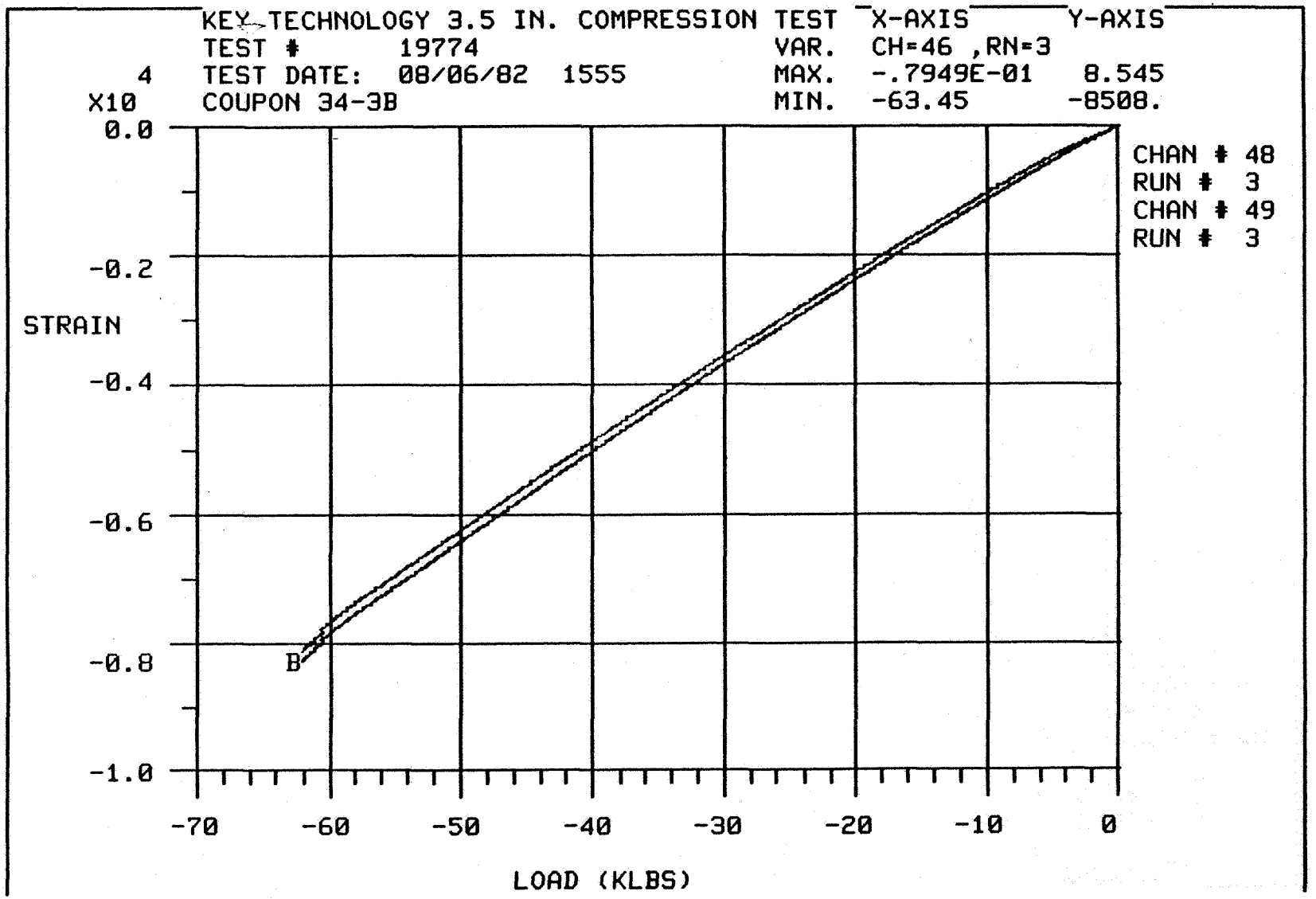
CONTINUED ON E.N. #

SIGNATURE WITNESSED Tom Gillette

8/7/82


KEY TECHNOLOGY 3.5 IN. COMPRESSION TEST
TEST # 19726
TEST DATE: 07/30/82 0901
COUPON 34-2B
X-AXIS Y-AXIS
VAR. CH=46 ,RN=3
MAX. -.2198 10.98
MIN. -63.96 -8756.
4
X10
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
STRAIN
CHAN # 48
RUN # 3
CHAN # 49
RUN # 3
B
A
-70
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19777
TEST DATE: 08/09/82 1030
COUPON 34-3A
X-AXIS
Y-AXIS
VAR. CH=46 ,RN=2
MAX. -.5490E-01 7.315
MIN. -63.59 -9372.
4
X10
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
STRAIN
A
B
CHAN # 48
RUN # 2
CHAN # 49
RUN # 2
-70
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY 3.5 IN. COMPRESSION TEST
TEST # 19774
TEST DATE: 08/06/82 1555
COUPON 34-3B
X-AXIS Y-AXIS
VAR. CH=46 ,RN=3
MAX. -.7949E-01 8.545
MIN. -63.45 -8508.
4
X10
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
STRAIN
B
CHAN # 48
RUN # 3
CHAN # 49
RUN # 3
-70
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)

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TO P. SANDIFER	DATE 8	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11268-17
FROM T. GILLETTE	17	SUBJECT KEY TECHNOLOGY IMPACTED COMPRESSION TESTS	REF
MODEL CRAD	82		WO EWA

CONTINUED FROM E.N. #

COUPON ID	CONDITION	THICKNESS END	THICKNESS CENTER	THICKNESS END	WIDTH	AREA IN²
22-1A	IMPACTED	.2704	.2687	.2675	4.999 4.999	1.344
22-1B		.2612	.2707	.2740	5.00 4.998	1.343
36-1A		.2755	.2715	.2715	4.999 4.997	1.363
36-1B		.2715	.2727	.2715	4.998 5.000	1.359
36-2A		.2713	.2668	.2686	4.998 4.998	1.344
15-4A		.2760	.2754	.2736	5.002 5.003	1.376

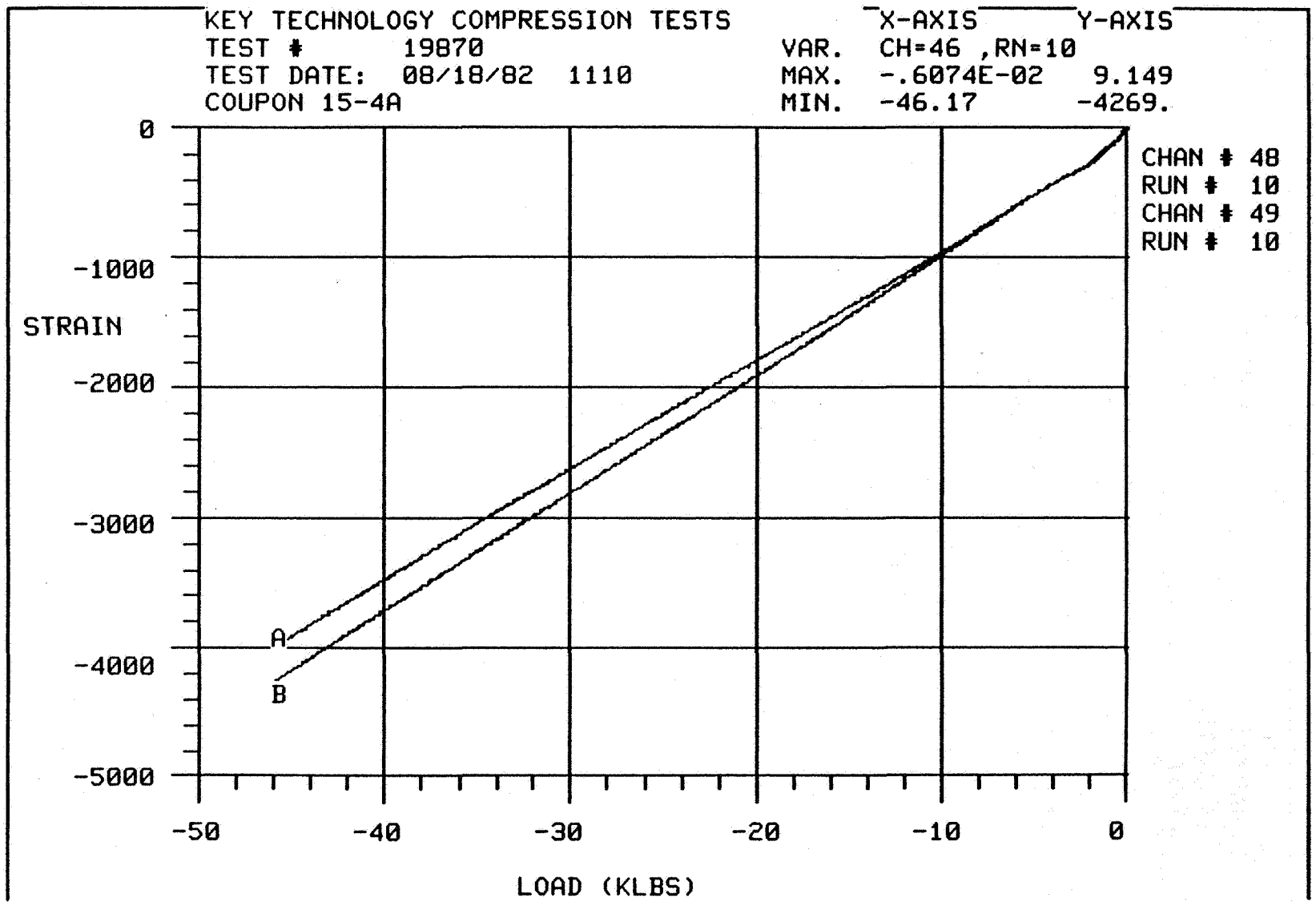
COUPON ID 2nds	FAILURE LOAD (KLBS)	GROSS STRESS (KSI)	STRAIN GAGE 1	STRAIN GAGE 2	REMARKS
22-1A	-43.67	-32.49	-4011	-4153	GAGE 1 IS ON IMPACTED SIDE
22-1B	-46.09	-34.32	-4074	-3974	
36-1A	-51.12	-37.50	-4092	-4437	
36-1B	-55.54	-40.86	-4977	-5001	
36-2A	-51.89	-38.61	-4375	-4866	
15-4A	-46.17	-33.56	-4013	-4269	

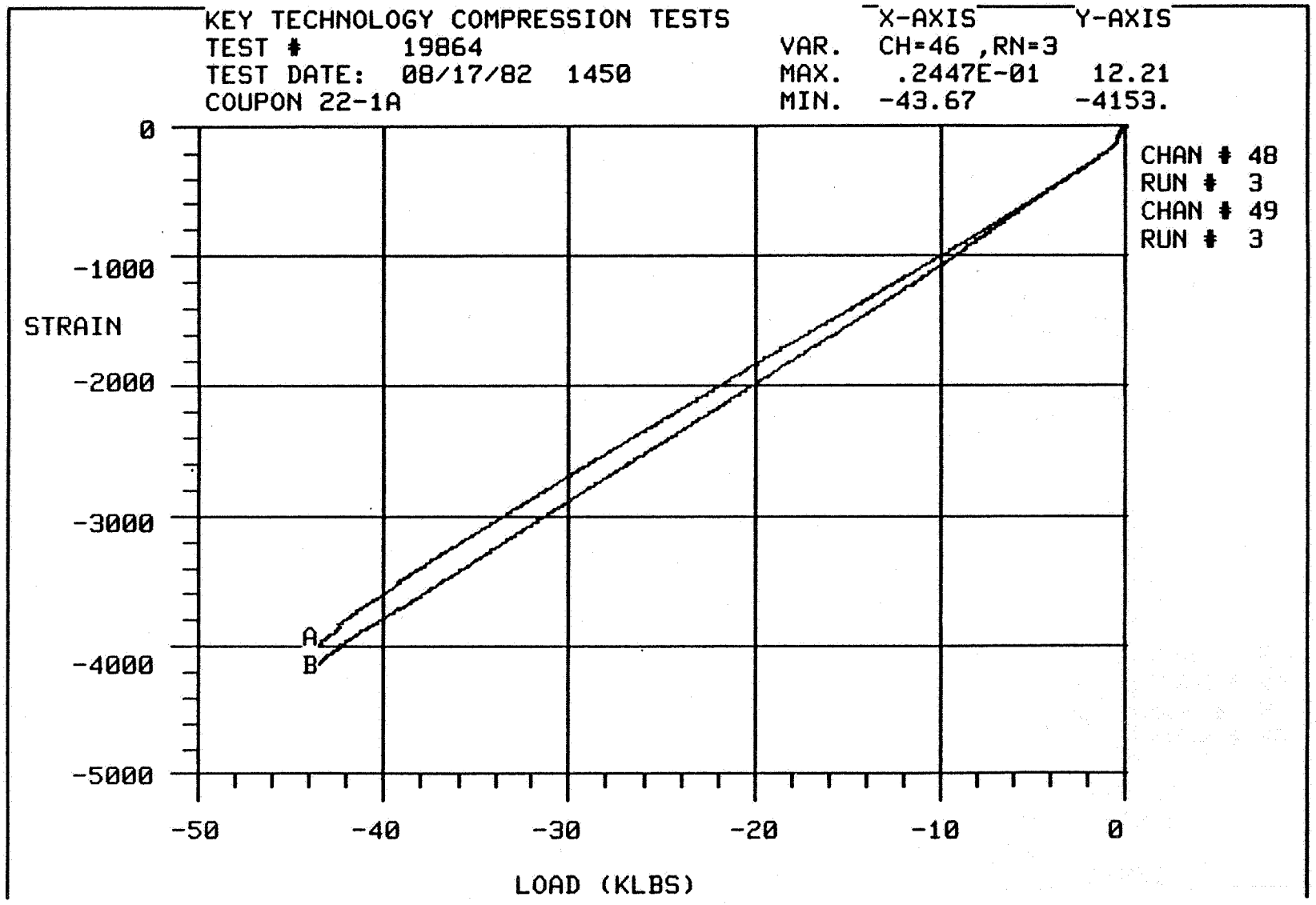
R CAL 5674 Fig 10, 0/2 B CAL

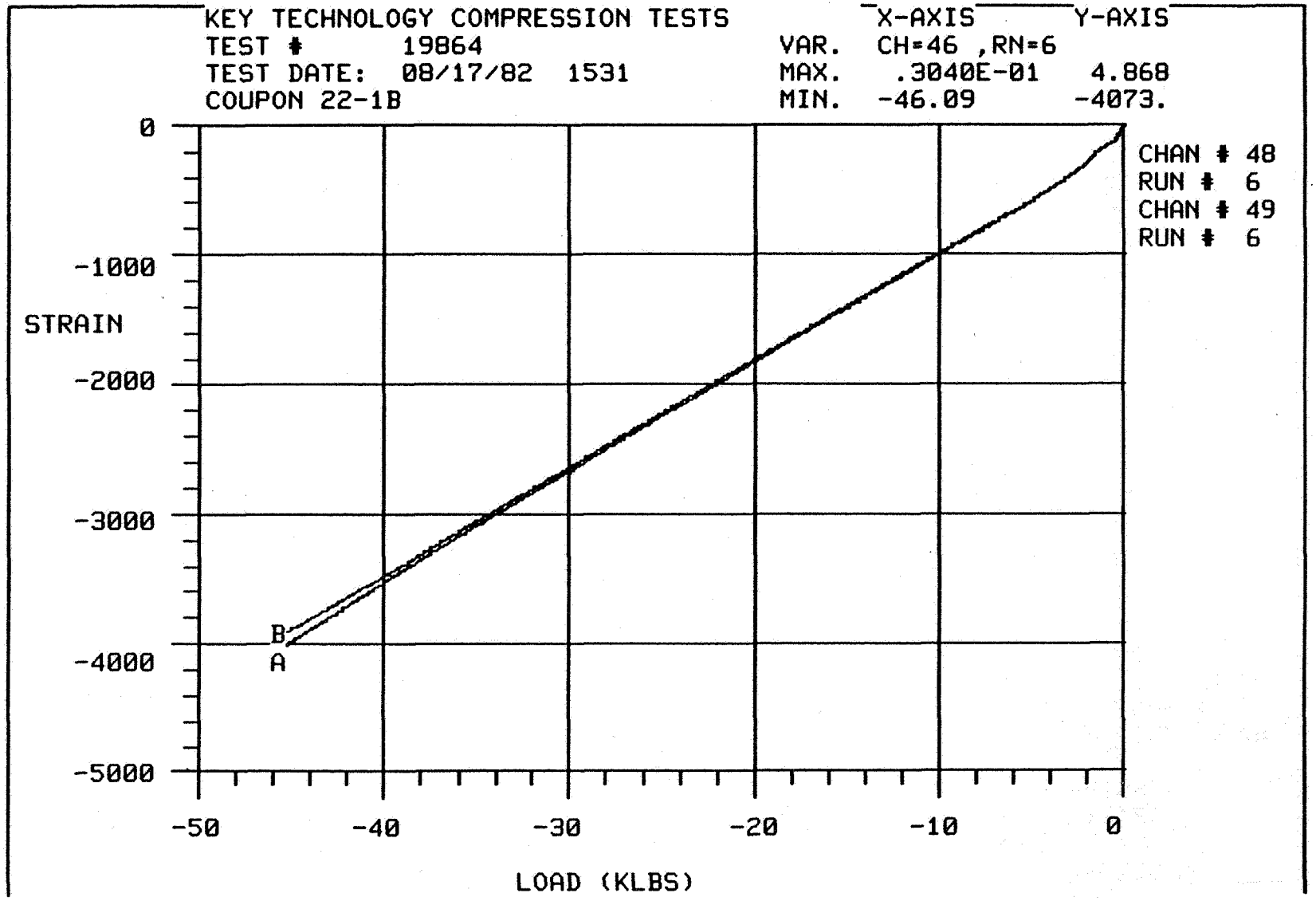
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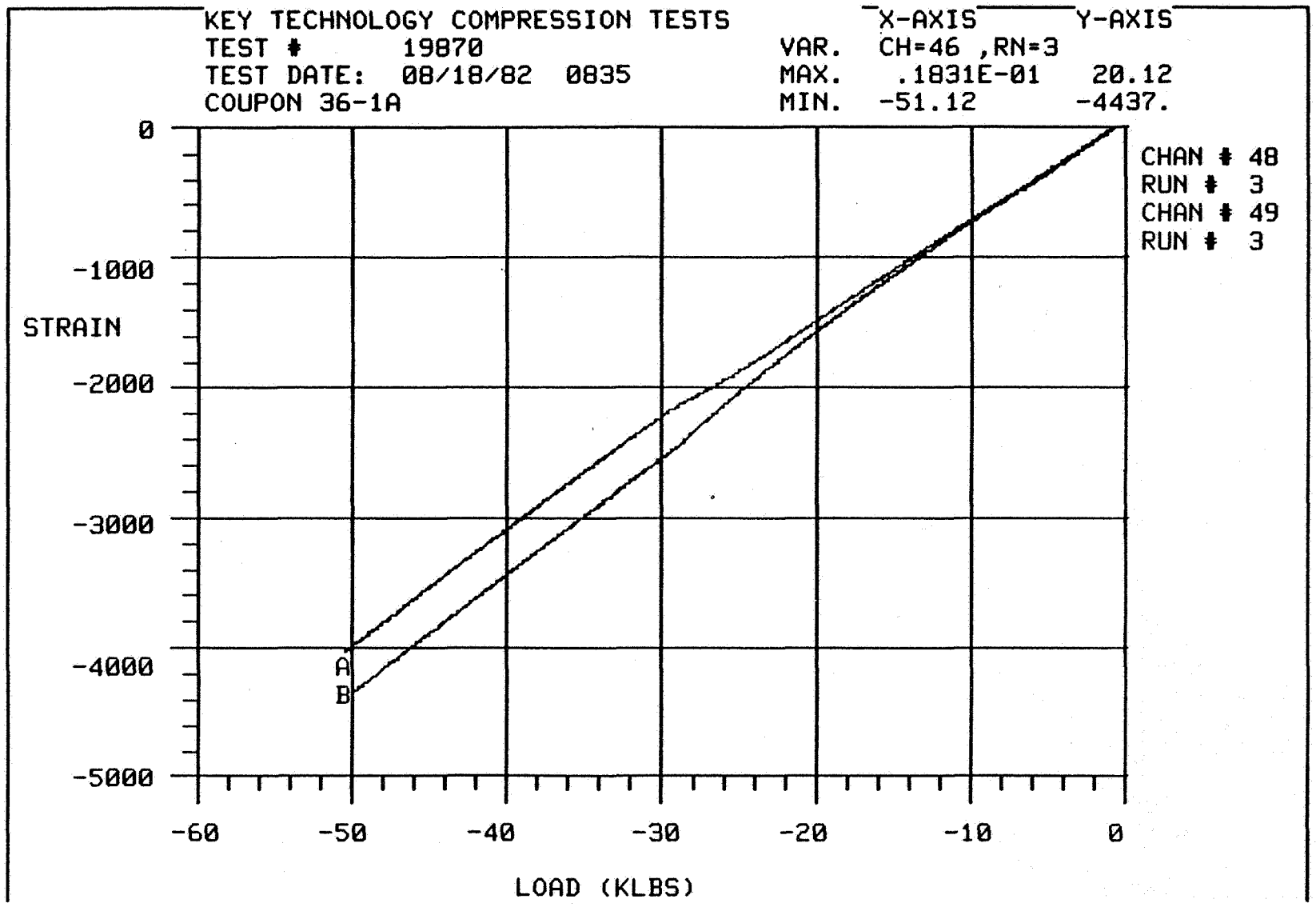
Tom Gillette

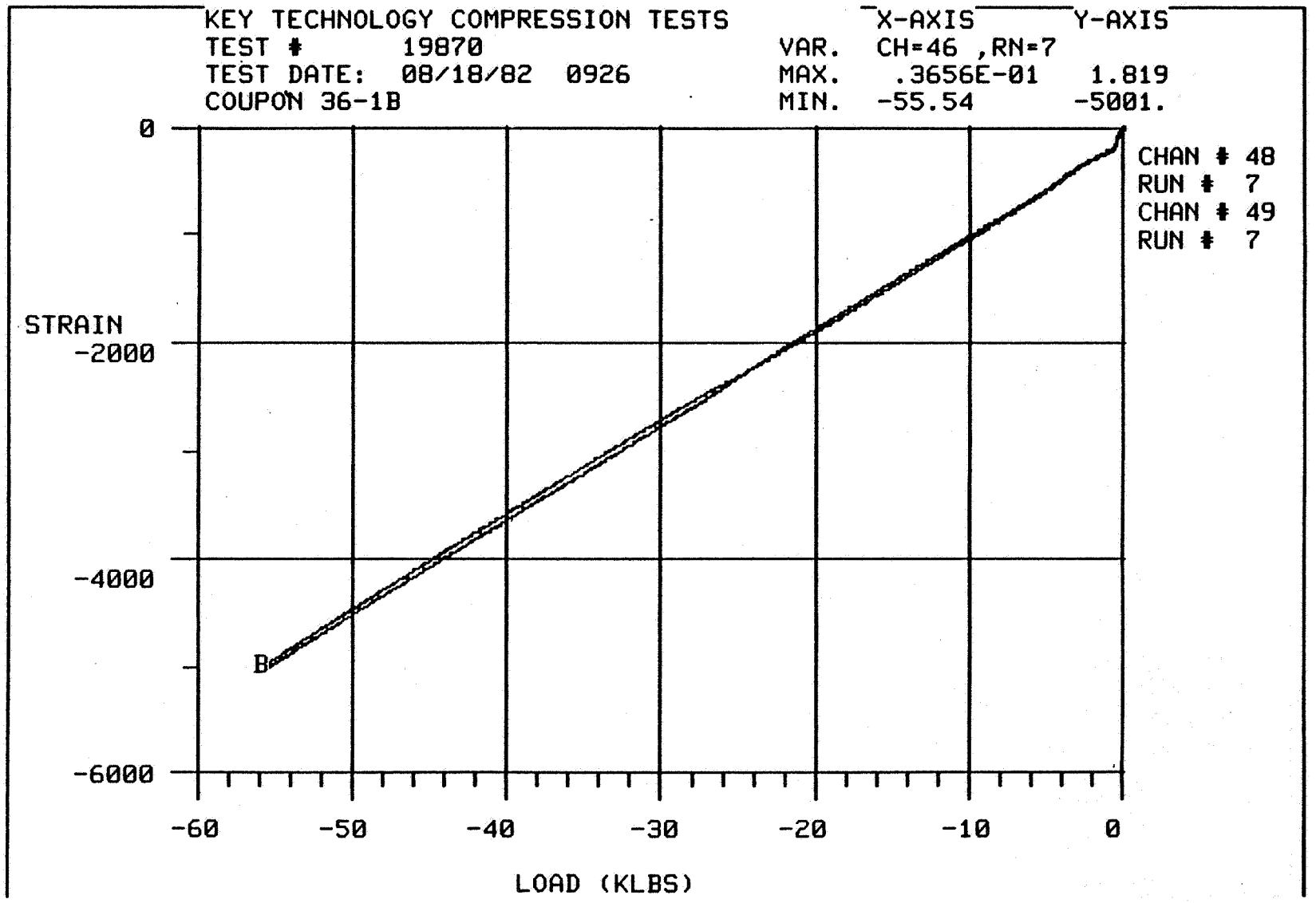
8/11/82

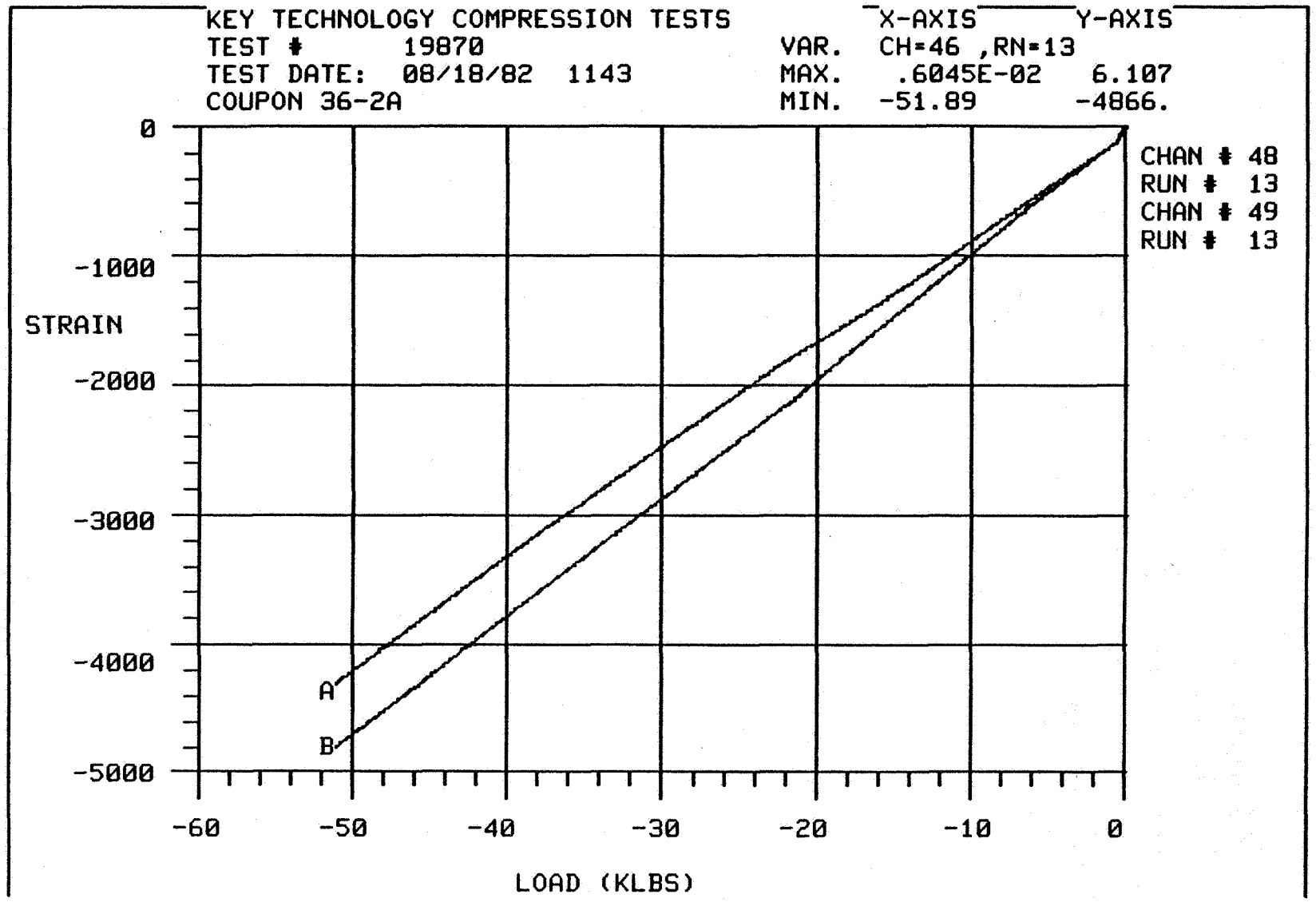

KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19870
TEST DATE: 08/18/82 1110
COUPON 15-4A
X-AXIS Y-AXIS
VAR. CH=46 ,RN=10
MAX. -.6074E-02 9.149
MIN. -46.17 -4269.
CHAN # 48
RUN # 10
CHAN # 49
RUN # 10
0
-1000
-2000
-3000
-4000
-5000
STRAIN
A
B
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19864
TEST DATE: 08/17/82 1450
COUPON 22-1A
X-AXIS
Y-AXIS
VAR. CH=46 ,RN=3
MAX. .2447E-01 12.21
MIN. -43.67 -4153.
CHAN # 48
RUN # 3
CHAN # 49
RUN # 3
0
-1000
-2000
-3000
-4000
-5000
STRAIN
A
B
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19864
TEST DATE: 08/17/82 1531
COUPON 22-1B
X-AXIS Y-AXIS
VAR. CH=46 ,RN=6
MAX. .3040E-01 4.868
MIN. -46.09 -4073.
CHAN # 48
RUN # 6
CHAN # 49
RUN # 6
0
-1000
-2000
-3000
-4000
-5000
STRAIN
B
A
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19870
TEST DATE: 08/18/82 0835
COUPON 36-1A
X-AXIS Y-AXIS
VAR. CH=46 ,RN=3
MAX. .1831E-01 20.12
MIN. -51.12 -4437.
CHAN # 48
RUN # 3
CHAN # 49
RUN # 3
0
-1000
-2000
-3000
-4000
-5000
STRAIN
A
B
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19870
TEST DATE: 08/18/82 0926
COUPON 36-1B
X-AXIS
Y-AXIS
VAR. CH=46 ,RN=7
MAX. .3656E-01 1.819
MIN. -55.54 -5001.
CHAN # 48
RUN # 7
CHAN # 49
RUN # 7
STRAIN
0
-2000
-4000
-6000
B
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TESTS
TEST # 19870
TEST DATE: 08/18/82 1143
COUPON 36-2A
X-AXIS Y-AXIS
VAR. CH=46 ,RN=13
MAX. .6045E-02 6.107
MIN. -51.89 -4866.
CHAN # 48
RUN # 13
CHAN # 49
RUN # 13
0
-1000
-2000
-3000
-4000
-5000
STRAIN
A
B
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)

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LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED CORPORATION
ENGINEERS NOTEBOOK

No. 1268-11

TO P. SANDIFER | DATE 7
FROM T. GILLETTE | 20
NOTE | 82

SUBJECT KEY TECHNOLOGY CREEP COMPRESSION TESTS Room Temp TESTS

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CONTINUED FROM E.N. #

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COUPON ID	HOLE DIA.	THICKNESS END	THICKNESS CENTER	THICKNESS END	WIDTH
34-4A	0.998	.2695	.2705	.2728	5.000 5.002
34-4B	1.000	.2688	.2727	.2725	5.001 5.000
35-1A	1.001	.2588	.2775	.2712	5.004 5.004
15-1A	IMPACTED	.2775	.2697	.2570	5.013 5.013
15-2A	↓	.2684	.2594	.2489	5.016 5.013
15-3A		.2798	.2762	.2630	.5013 .5015
15-2B		.2675	.2674	.2726	.5012 .5011
15-3B		.2733	.2758	.2765	.5012 .5014

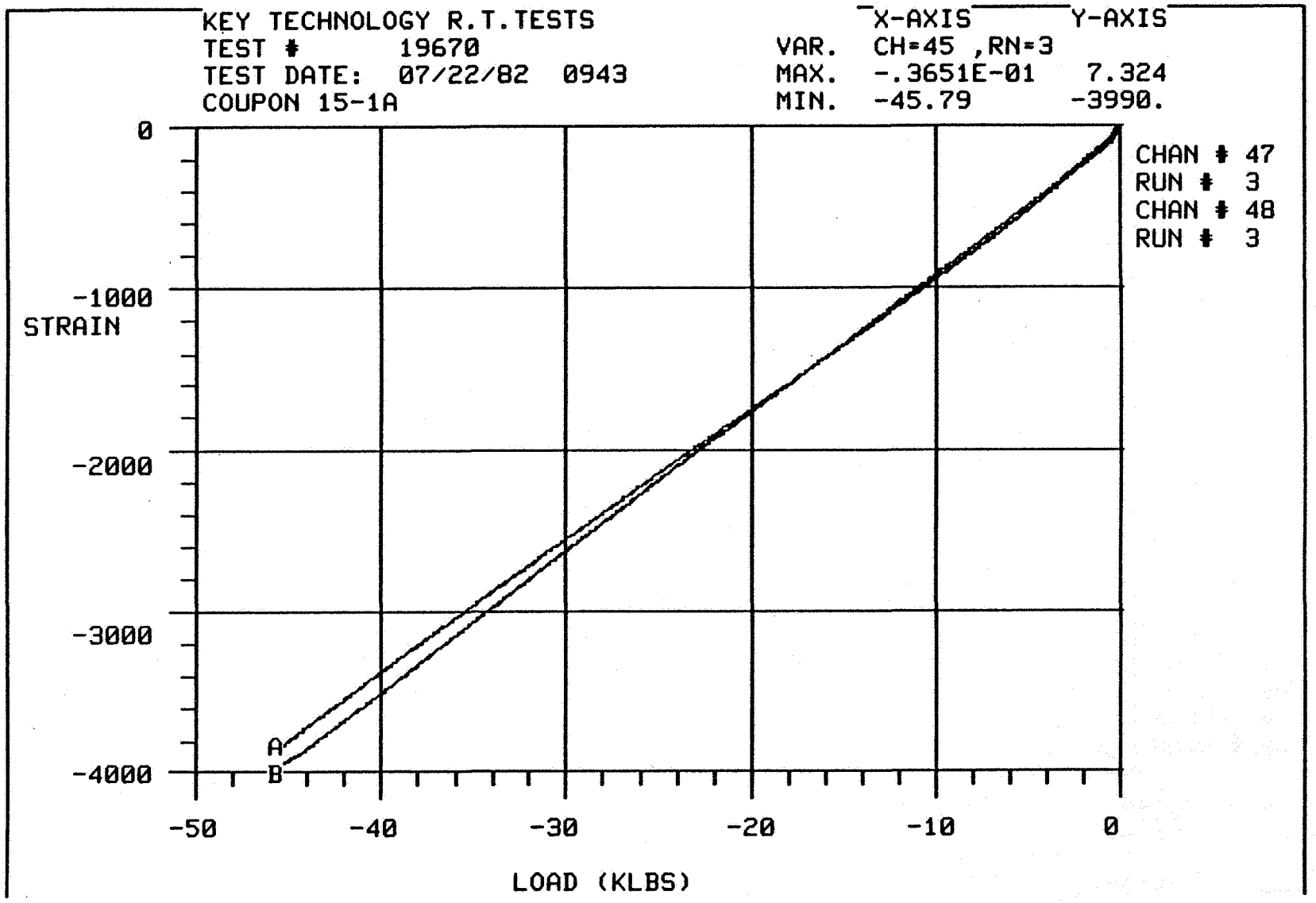
COUPON ID	FAILURE LOAD	STRESS (GROSS AREA)	STRAIN NO1 (A)	STRAIN NO2 (B)	REMARKS
34-4A	-46.80	-34.54	-3568	-4046	GAGES INDICATE SMALL AMOUNT OF BUCKLING
34-4B	-42.36	-31.22	-3400	-3450	
35-1A	-48.27	-35.84	-3832	-3983	
15-1A	-45.79	-34.07	-3882	-3991	SPECIMEN ROTATED 180°
15-2A	-44.80	-34.51	-4052	-3684	"
15-3A	-41.09	-30.02	-3444	-3340	
15-2B	-42.91	-31.81	-3848	-3533	
15-3B	-39.29	-28.49	-3368	-3416	FIXTURE ROTATED "

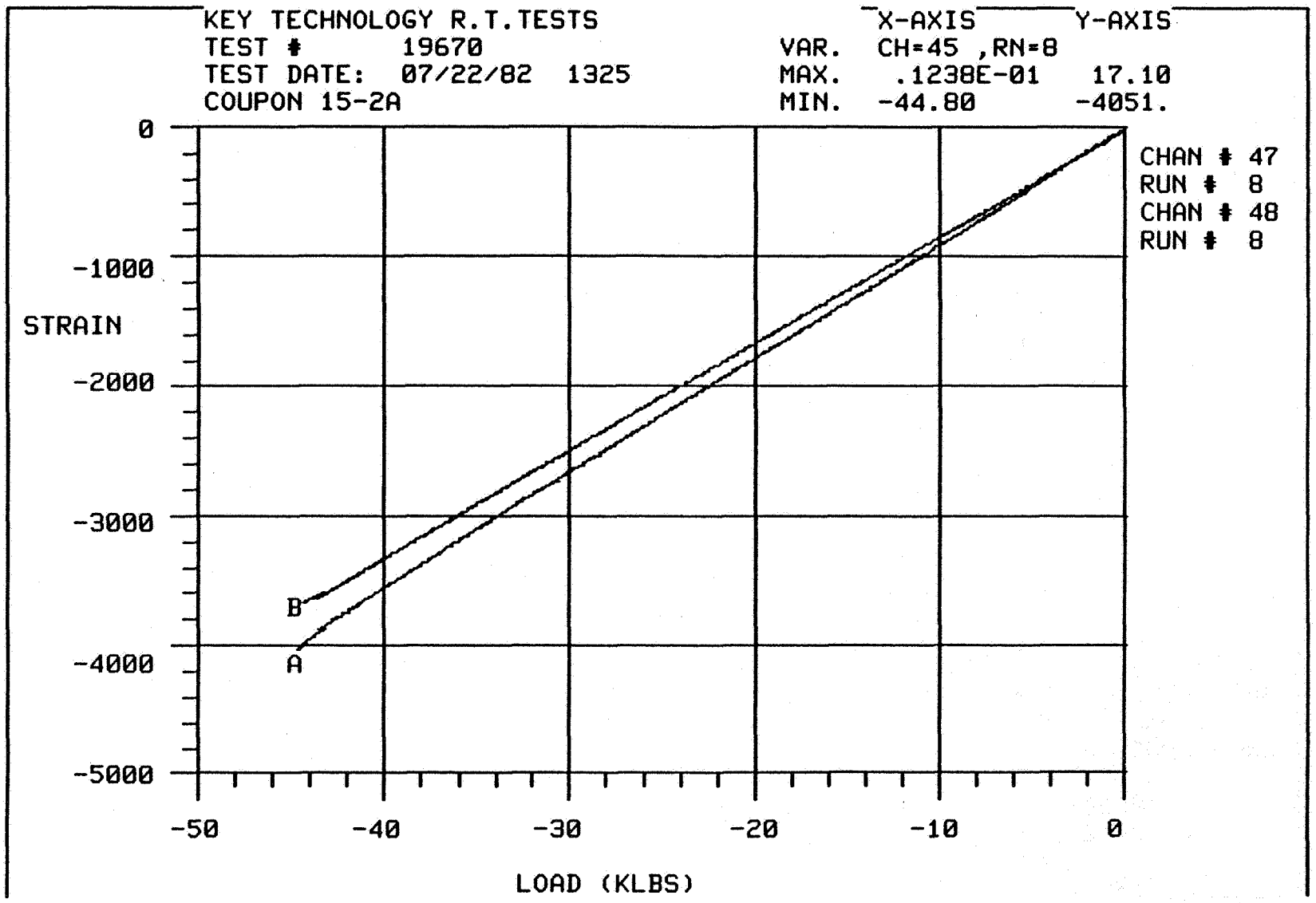
R CAL FOR GAGES 1035 με

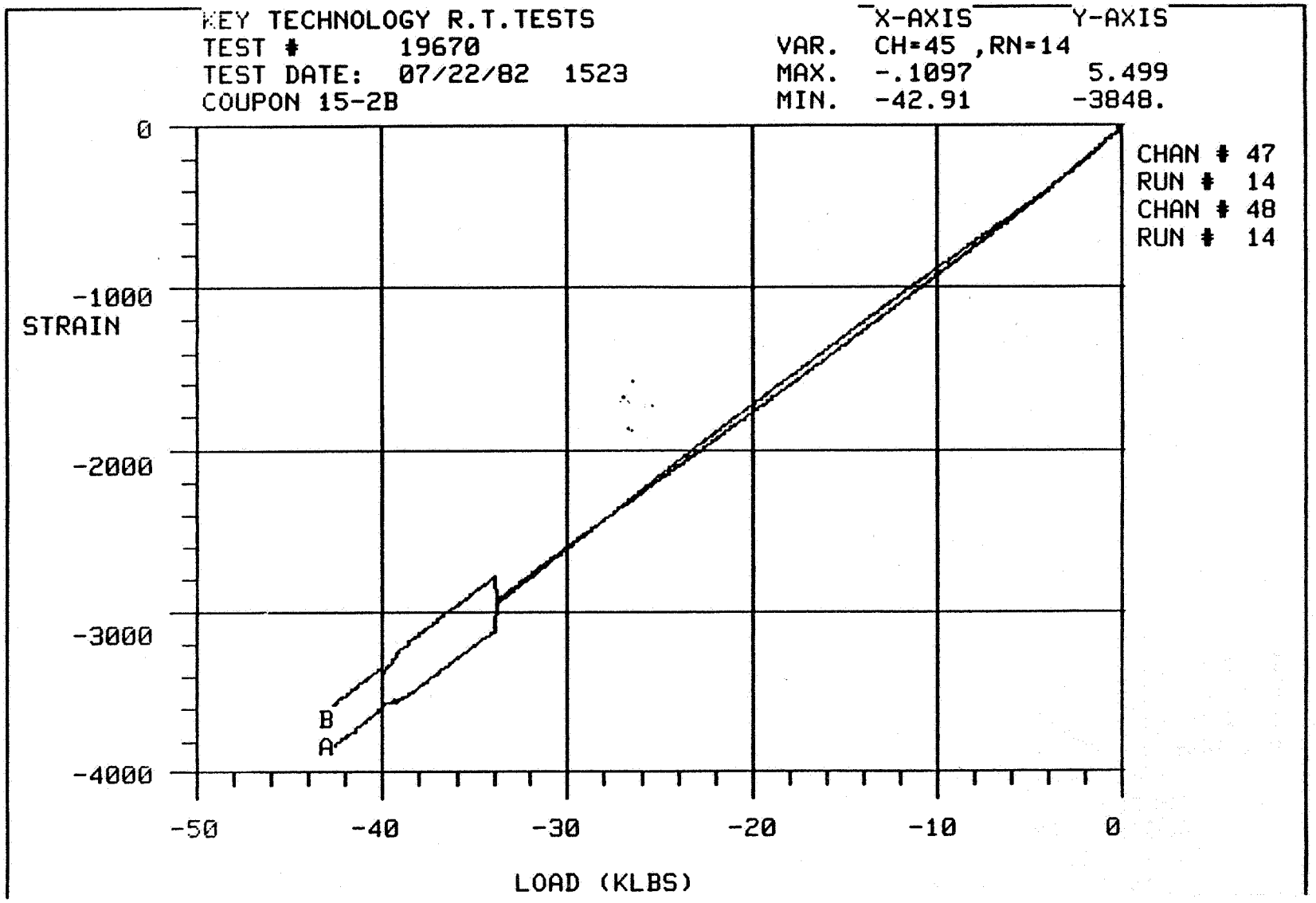
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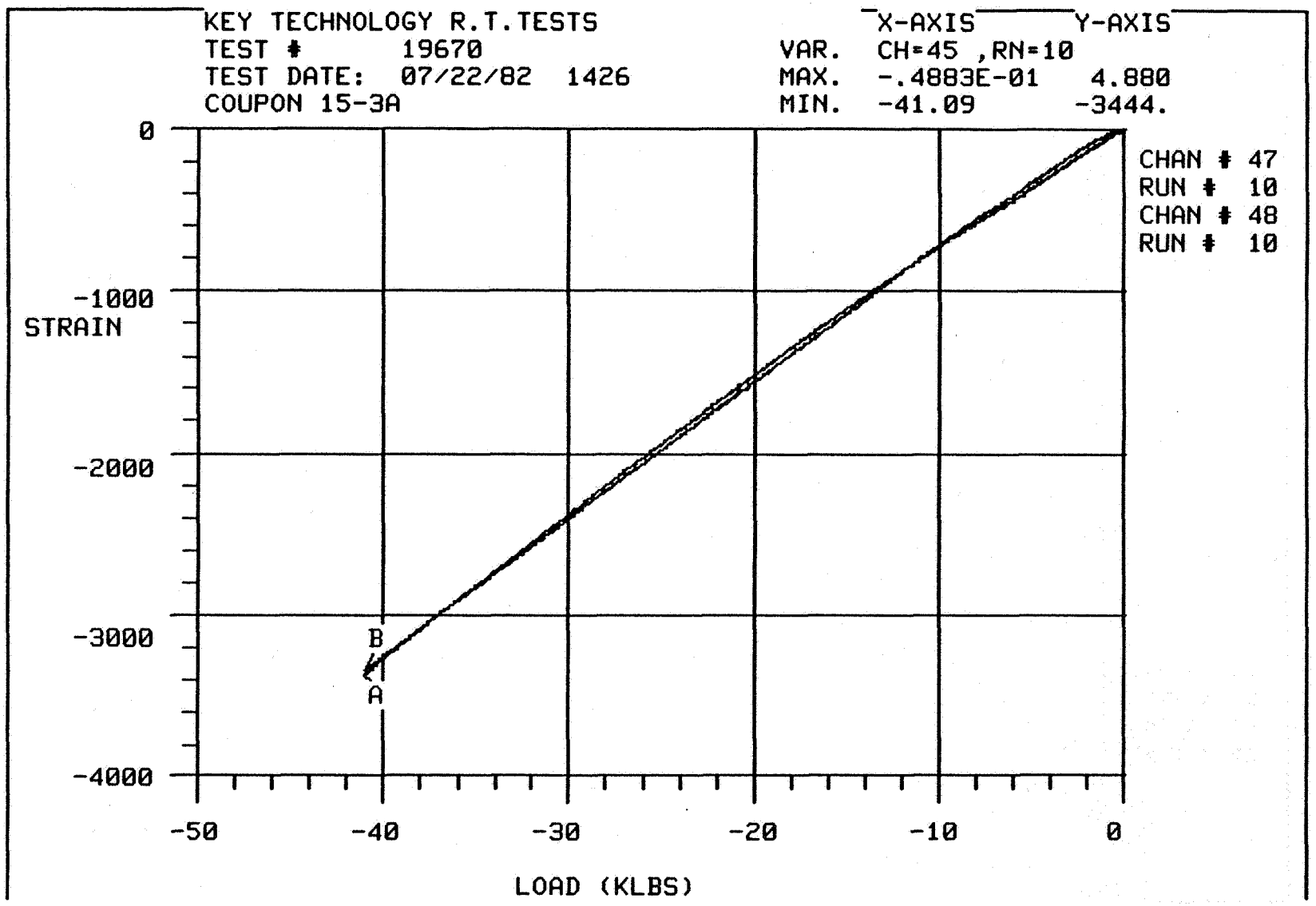
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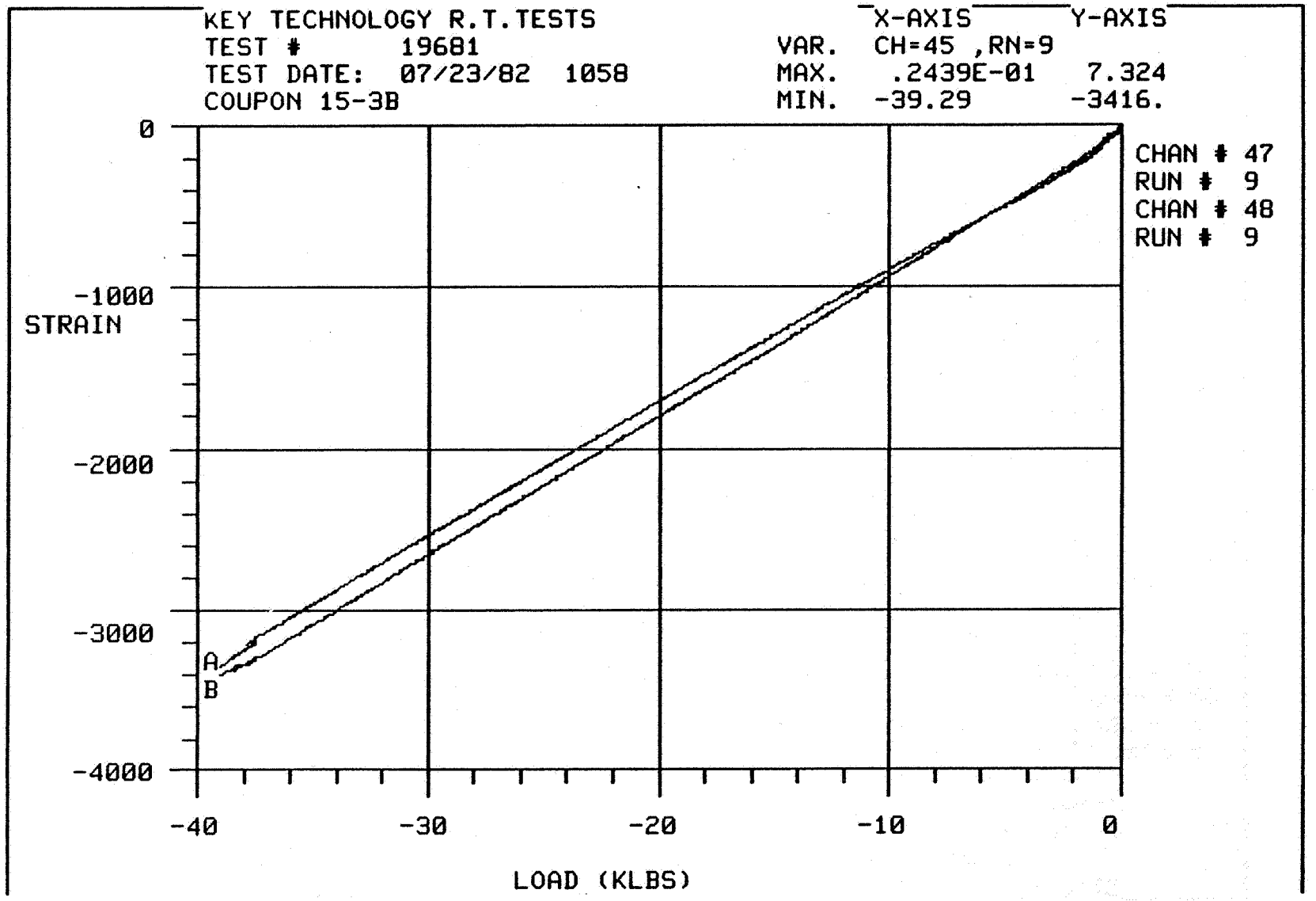
7/24/82

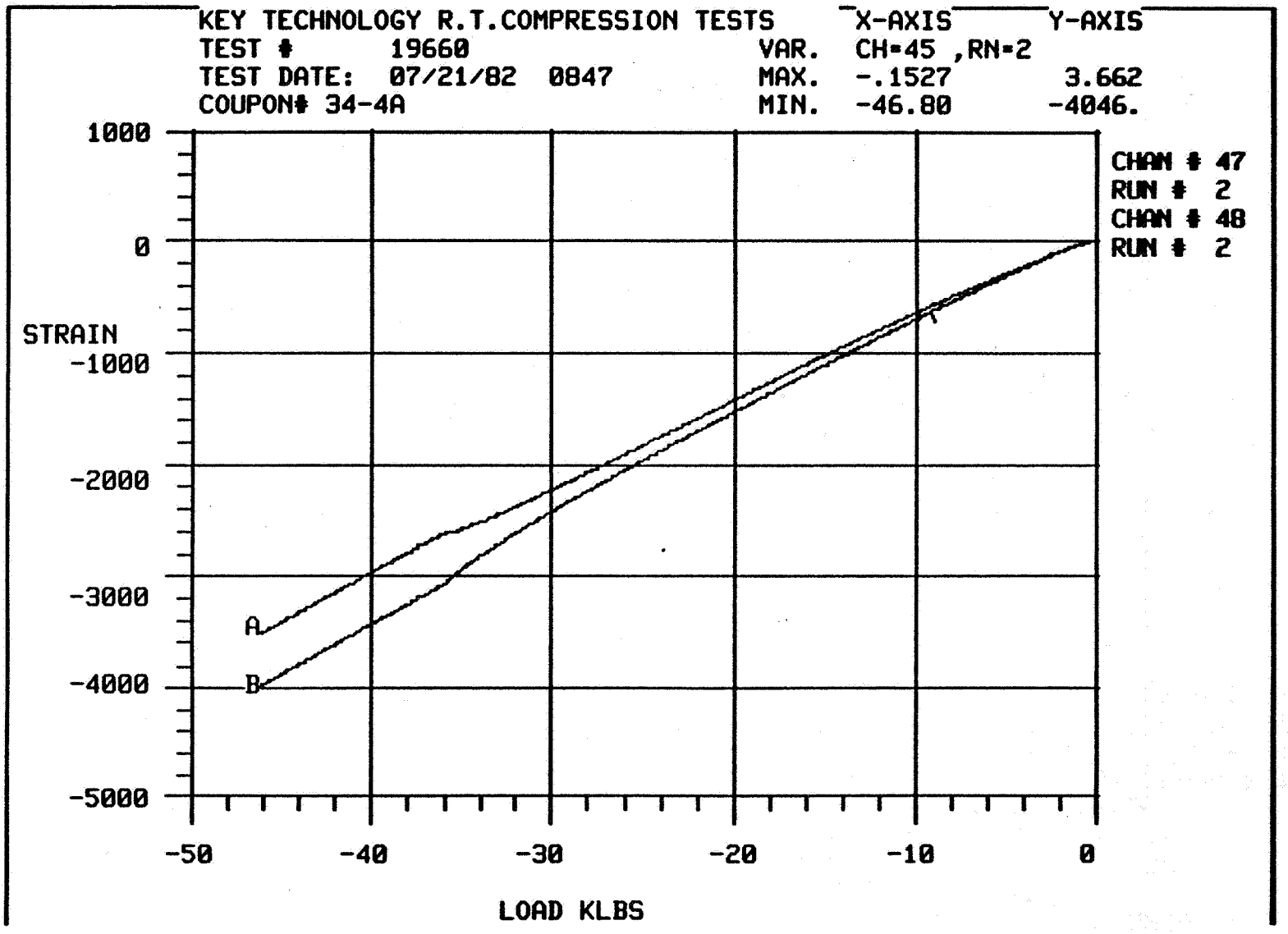

KEY TECHNOLOGY R.T.TESTS
TEST # 19670
TEST DATE: 07/22/82 0943
COUPON 15-1A
X-AXIS Y-AXIS
VAR. CH=45 ,RN=3
MAX. -.3651E-01 7.324
MIN. -45.79 -3990.
CHAN # 47
RUN # 3
CHAN # 48
RUN # 3
0
-1000
-2000
-3000
-4000
STRAIN
A
B
-50
-40
-30
-20
-10
0
LOAD (KLBS)

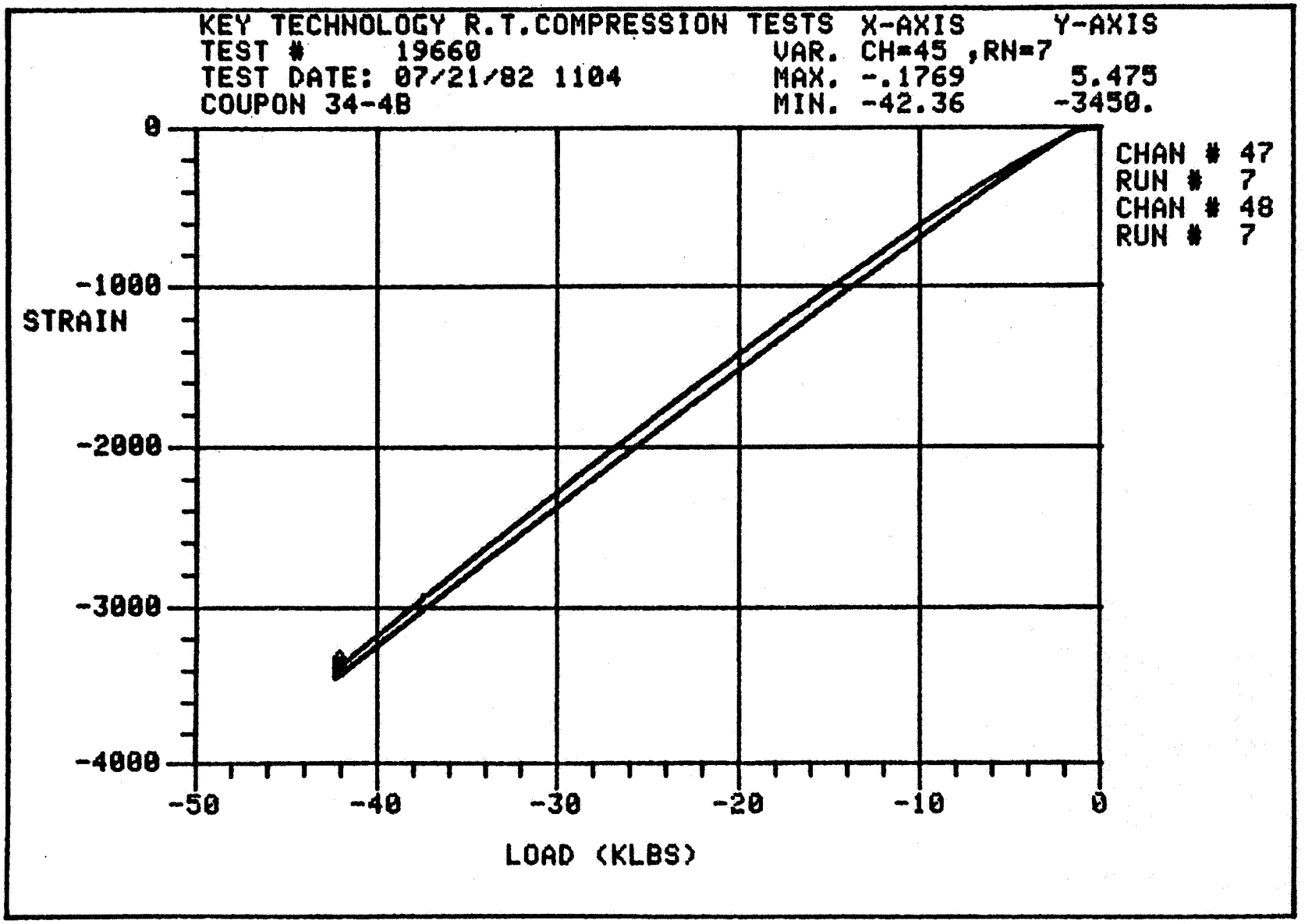

KEY TECHNOLOGY R.T.TESTS
TEST # 19670
TEST DATE: 07/22/82 1325
COUPON 15-2A
X-AXIS
Y-AXIS
VAR. CH=45 ,RN=8
MAX. .1238E-01 17.10
MIN. -44.80 -4051.
CHAN # 47
RUN # 8
CHAN # 48
RUN # 8
0
-1000
-2000
-3000
-4000
-5000
STRAIN
B
A
-50
-40
-30
-20
-10
0
LOAD (KLBS)

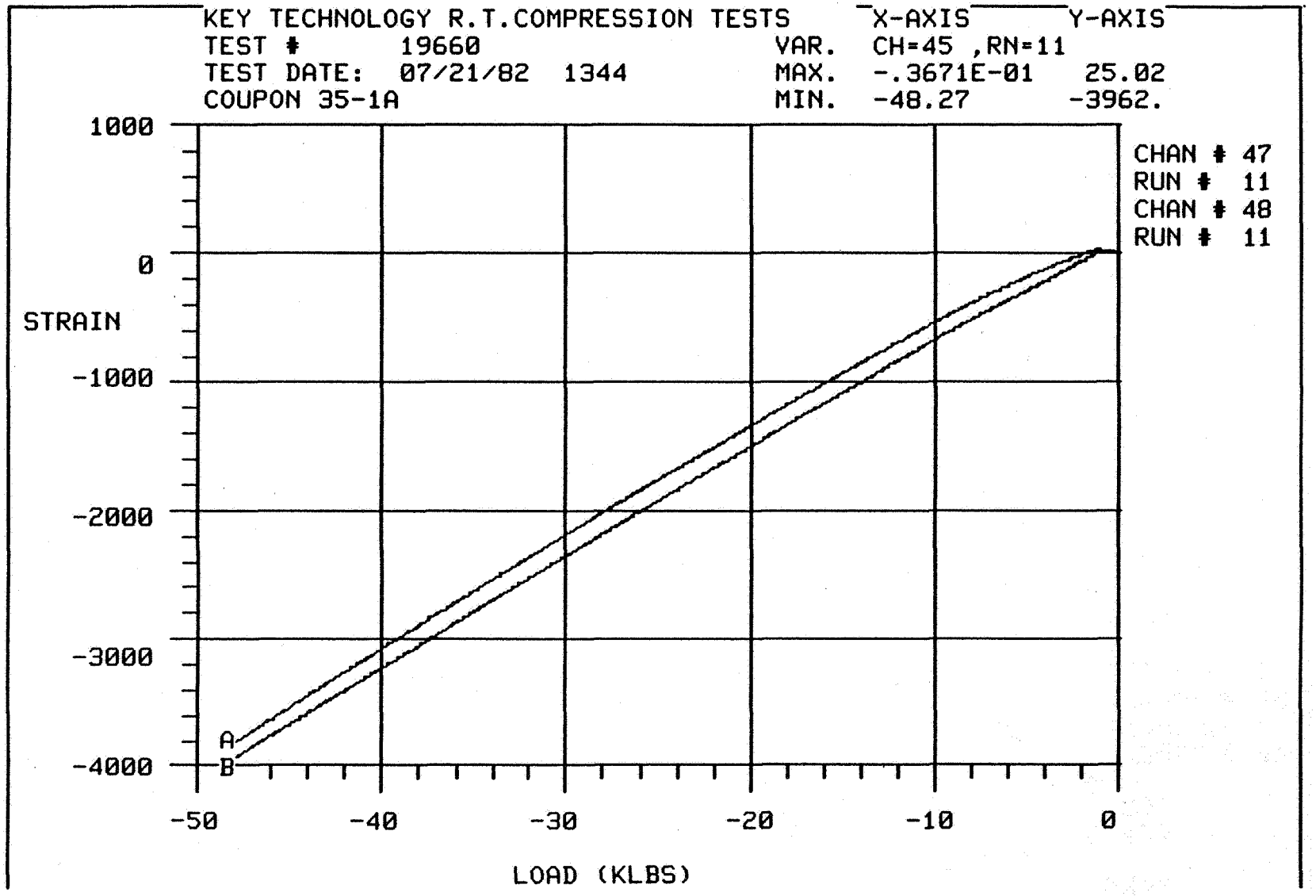

KEY TECHNOLOGY R.T.TESTS
TEST # 19670
TEST DATE: 07/22/82 1523
COUPON 15-2B
X-AXIS Y-AXIS
VAR. CH=45 ,RN=14
MAX. -.1097 5.499
MIN. -42.91 -3848.
CHAN # 47
RUN # 14
CHAN # 48
RUN # 14
0
-1000
-2000
-3000
-4000
STRAIN
B
A
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY R.T.TESTS
TEST # 19670
TEST DATE: 07/22/82 1426
COUPON 15-3A
X-AXIS Y-AXIS
VAR. CH=45 ,RN=10
MAX. -.4883E-01 4.880
MIN. -41.09 -3444.
CHAN # 47
RUN # 10
CHAN # 48
RUN # 10
0
-1000
-2000
-3000
-4000
STRAIN
B
A
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY R.T.TESTS
TEST # 19681
TEST DATE: 07/23/82 1058
COUPON 15-3B
X-AXIS Y-AXIS
VAR. CH=45 ,RN=9
MAX. .2439E-01 7.324
MIN. -39.29 -3416.
CHAN # 47
RUN # 9
CHAN # 48
RUN # 9
0
-1000
STRAIN
-2000
-3000
-4000
A
B
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY R.T.COMPRESSION TESTS
TEST # 19660
TEST DATE: 07/21/82 0847
COUPON# 34-4A
X-AXIS
Y-AXIS
VAR. CH=45 ,RN=2
MAX. -.1527 3.662
MIN. -46.80 -4046.
CHAN # 47
RUN # 2
CHAN # 48
RUN # 2
1000
0
-1000
-2000
-3000
-4000
-5000
STRAIN
-50
-40
-30
-20
-10
0
LOAD KLBS
A
B


KEY TECHNOLOGY R.T.COMPRESSION TESTS
TEST # 19660
TEST DATE: 07/21/82 1104
COUPON 34-4B
X-AXIS Y-AXIS
VAR. CH=45 ,RN=7
MAX. -.1769 5.475
MIN. -42.36 -3450.
CHAN # 47
RUN # 7
CHAN # 48
RUN # 7
0
-1000
-2000
-3000
-4000
STRAIN
-50
-40
-30
-20
-10
0
LOAD (KLBS)


KEY TECHNOLOGY R.T.COMPRESSION TESTS
TEST # 19660
TEST DATE: 07/21/82 1344
COUPON 35-1A
X-AXIS
Y-AXIS
VAR. CH=45 ,RN=11
MAX. -.3671E-01 25.02
MIN. -48.27 -3962.
CHAN # 47
RUN # 11
CHAN # 48
RUN # 11
1000
0
-1000
-2000
-3000
-4000
STRAIN
A
B
-50
-40
-30
-20
-10
0
LOAD (KLBS)

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P. SANDIFER | DATE 8
T. GILLETTE | 19
CRAD | 82

LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED CORPORATION
ENGINEERS NOTEBOOK

Nº 11268-16

SUBJECT KEY TECHNOLOGY
180 °F TESTS

REF

NO. LWA

COUPON ID	CONDITION	THICKNESS END	THICKNESS CENTER	THICKNESS END	WIDTH	AREA IN²
16-3B	180 °F UNIMPACTED MOISTURE CONDITIONED	.2745	.2747	.2747	x5.004 x5.005	1.374
16-4A	↓	.2715	.2734	.2643	x5.004 x5.005	1.349
16-4B		.2717	.2758	.2777	x5.003 x5.004	1.376

COUPON ID	FAILURE LOAD (KLB)	FAILURE STRESS (KSI)	STRAIN GAGE #1	STRAIN GAGE #2	REMARKS
16-3B	-93.36	-67.94	-9107	-6584	R CAL 5074 AL for 10012 SS
16-4A	-82.46	-61.12	-7657	-6724	
16-4B	-72.96	~~-67.04~~ -53.02	~~-6709~~	-6545	

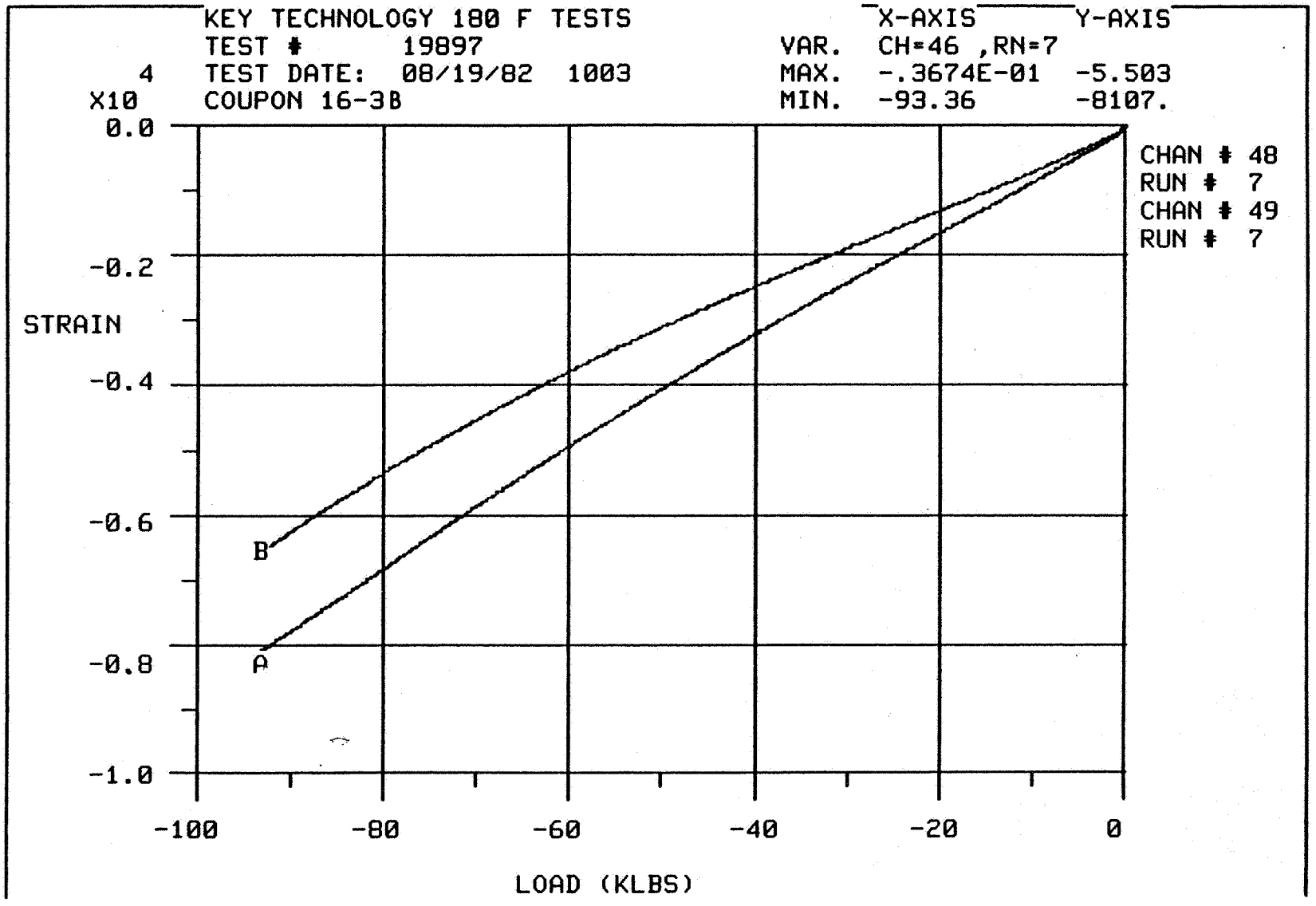
ROOM TEMPERATURE TESTS
PANEL 104

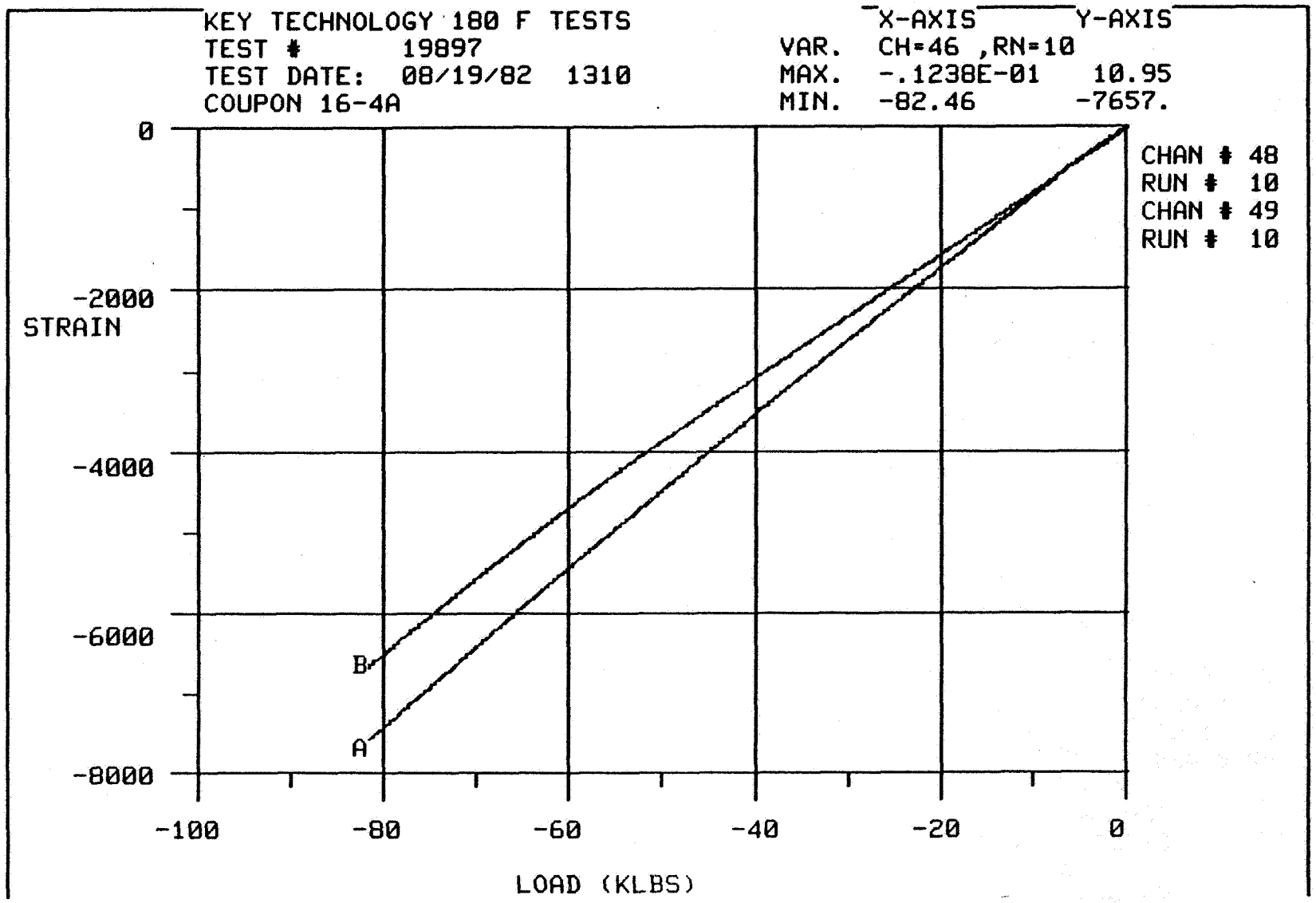
COUPON ID	CONDITION	THICKNESS END	THICKNESS CENTER	THICKNESS END	WIDTH	AREA IN²
104-2A	UNIMPACTED	.2691	.2640	.2446	3.423 3.423	.9066
104-2B	↓	.2698	.2690	.2712	3.423 3.423	.9431

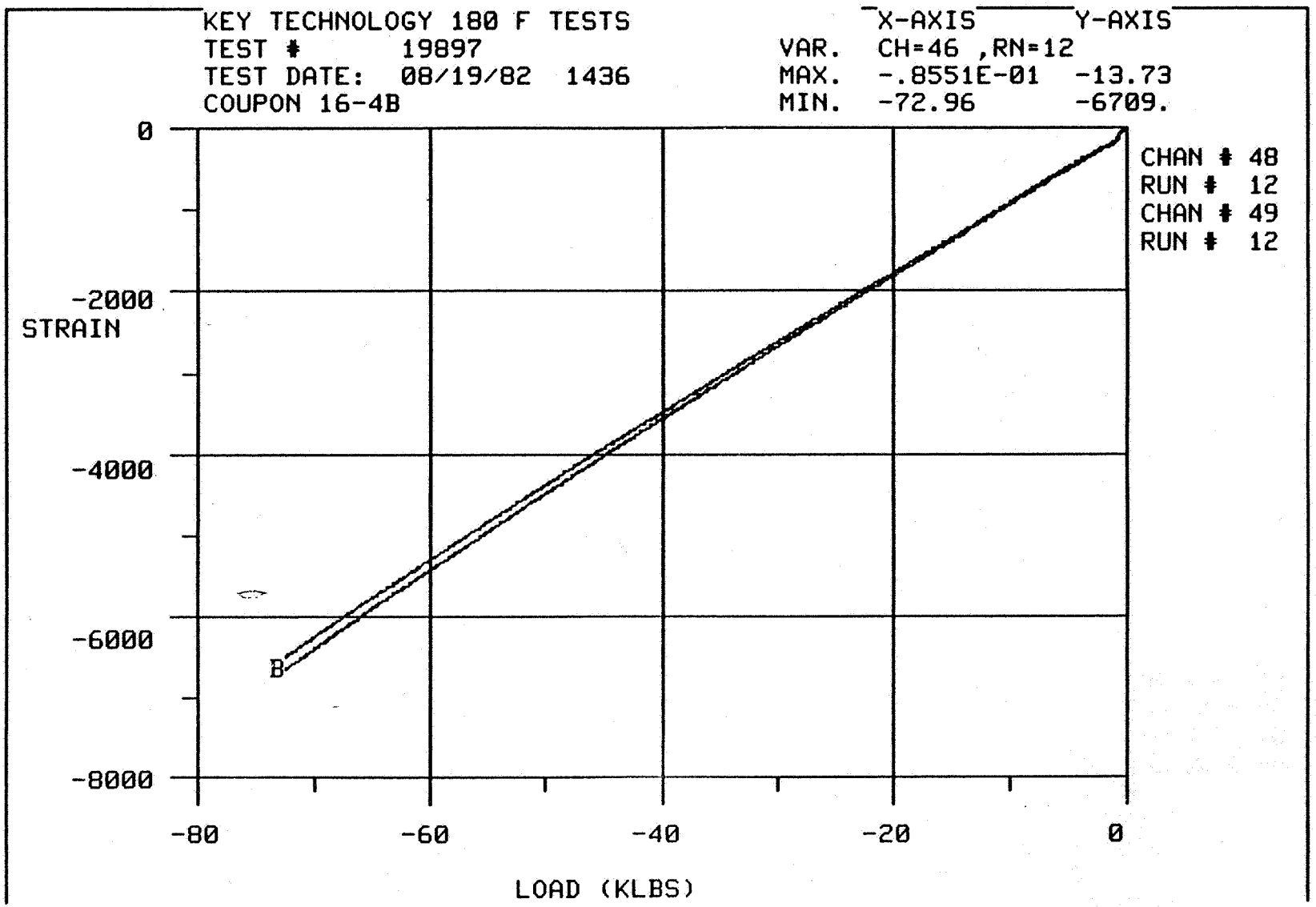
COUPON ID	FAILURE LOAD	FAILURE STRESS	STRAIN GAGE 1	STRAIN GAGE 2
104-2A	-65.08	-71.28	-9096	-8434
104-2B	-59.98	-63.60	-7382	-8397

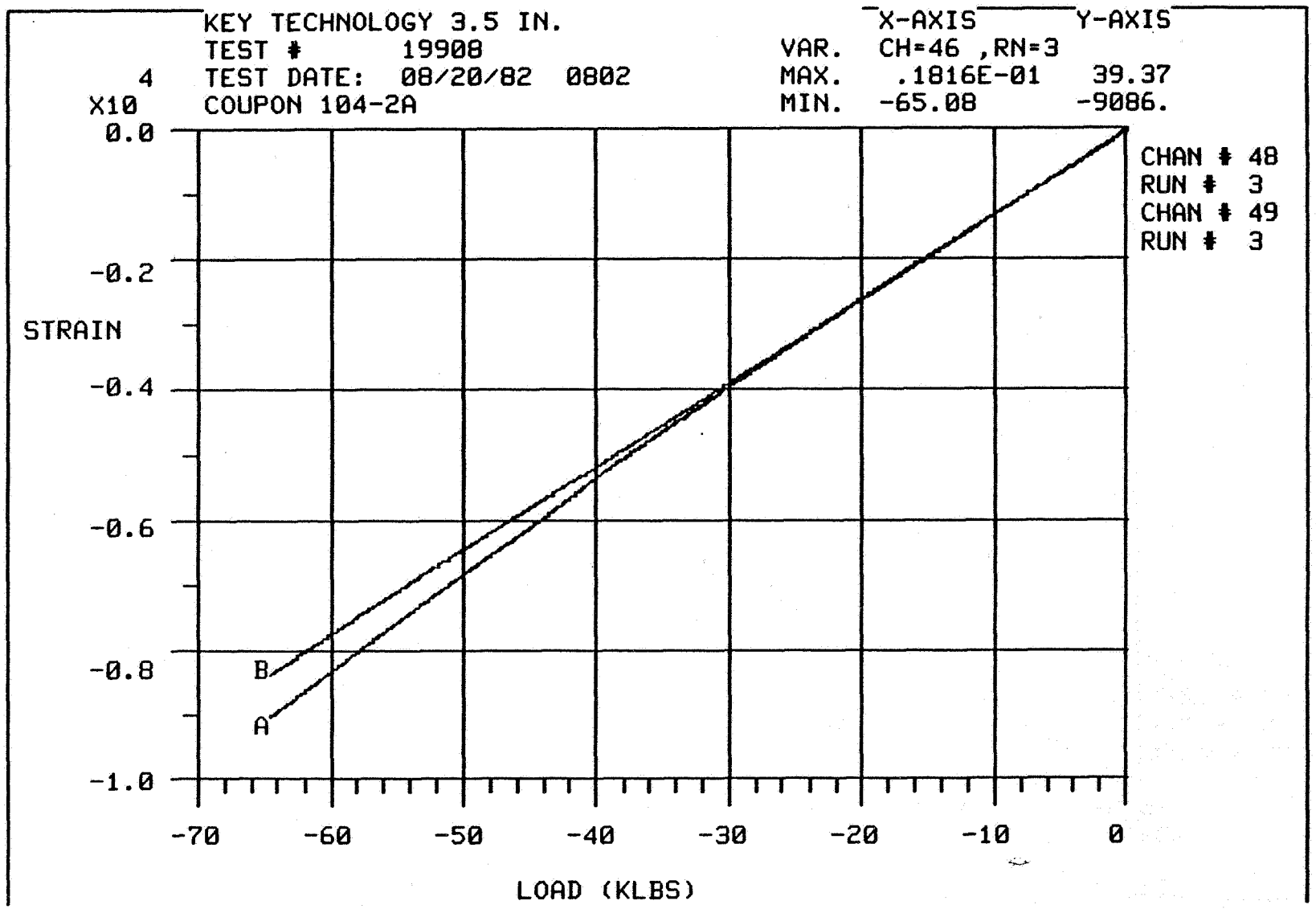
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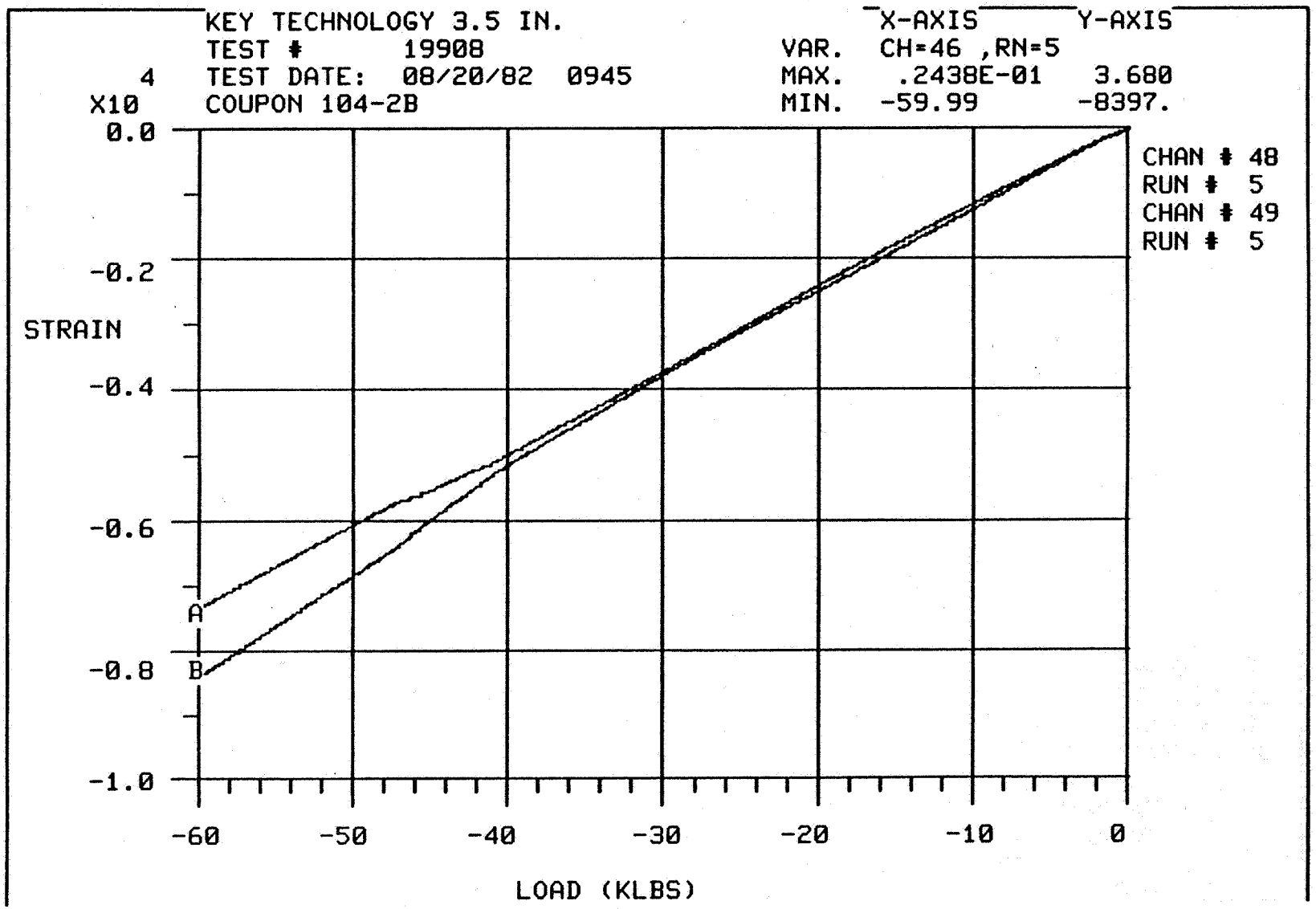
8/20/82


KEY TECHNOLOGY 180 F TESTS
TEST # 19897
TEST DATE: 08/19/82 1003
COUPON 16-3B
X-AXIS Y-AXIS
VAR. CH=46 ,RN=7
MAX. -.3674E-01 -5.503
MIN. -93.36 -8107.
4
X10
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
STRAIN
-100
-80
-60
-40
-20
0
LOAD (KLBS)
CHAN # 48
RUN # 7
CHAN # 49
RUN # 7
B
A


KEY TECHNOLOGY 180 F TESTS
TEST # 19897
TEST DATE: 08/19/82 1310
COUPON 16-4A
X-AXIS Y-AXIS
VAR. CH=46 ,RN=10
MAX. -.1238E-01 10.95
MIN. -82.46 -7657.
CHAN # 48
RUN # 10
CHAN # 49
RUN # 10
0
-2000
-4000
-6000
-8000
STRAIN
-100
-80
-60
-40
-20
0
LOAD (KLBS)
B
A


KEY TECHNOLOGY 180 F TESTS
TEST # 19897
TEST DATE: 08/19/82 1436
COUPON 16-4B
X-AXIS Y-AXIS
VAR. CH=46 ,RN=12
MAX. -.8551E-01 -13.73
MIN. -72.96 -6709.
CHAN # 48
RUN # 12
CHAN # 49
RUN # 12
0
-2000
-4000
-6000
-8000
STRAIN
-80
-60
-40
-20
0
LOAD (KLBS)
B


KEY TECHNOLOGY 3.5 IN.
TEST # 19908
TEST DATE: 08/20/82 0802
COUPON 104-2A
X-AXIS Y-AXIS
VAR. CH=46 ,RN=3
MAX. .1816E-01 39.37
MIN. -65.08 -9086.
4
X10
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
STRAIN
B
A
-70
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)
CHAN # 48
RUN # 3
CHAN # 49
RUN # 3


KEY TECHNOLOGY 3.5 IN.
TEST # 19908
TEST DATE: 08/20/82 0945
COUPON 104-2B
X-AXIS Y-AXIS
VAR. CH=46 ,RN=5
MAX. .2438E-01 3.680
MIN. -59.99 -8397.
4
X10
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
STRAIN
A
B
CHAN # 48
RUN # 5
CHAN # 49
RUN # 5
-60
-50
-40
-30
-20
-10
0
LOAD (KLBS)

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TO P. SANDIFER	DATE 6	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11268-10
FROM T. GILLETTE	22	SUBJECT KEY TECHNOLOGY GRIER COMPRESSION TEST RT	REP ETR C-1-82
MODEL	82		WO EWA

CONTINUED FROM E.N. #

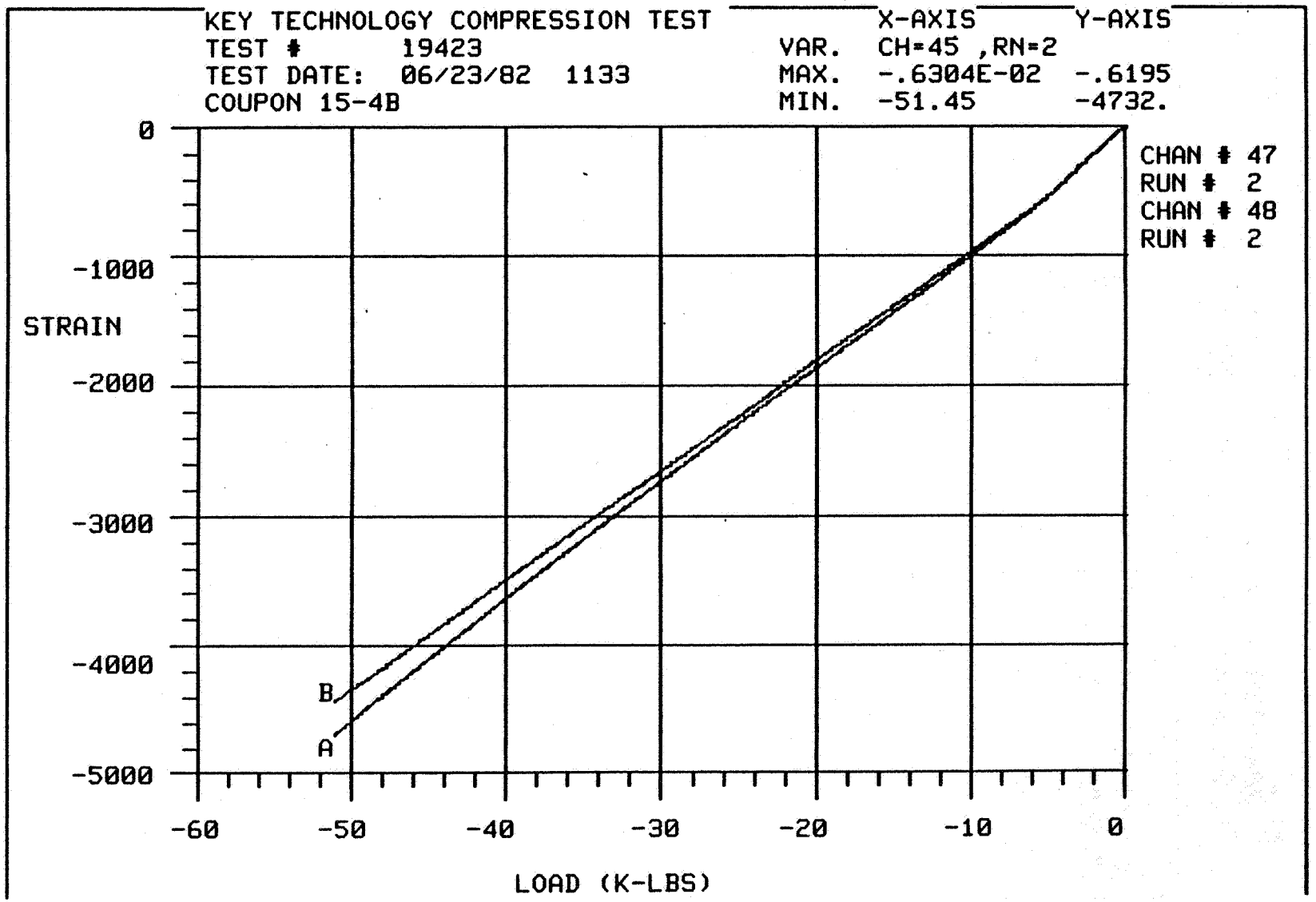
COUPON ID #	HOLE DIA (IN)	THICKNESS END	THICKNESS CENTER	THICKNESS END	WIDTH
15-4B	.999	.2685	.2655	.2555	5.003 5.003
16-1A	.993	.2795	.2780	26 55	5.001 5.003
16-1B	.998	.2775	.2730	.2720	5.000 5.001
16-2A	NA	.2595	.2700	.2740	5.006 NA/AVIALABLE
16-2B	NA	.2640	.2595	.2605	5.001 5.001
16-3A	NA	.2625	.2640	.2645	5.003 5.003

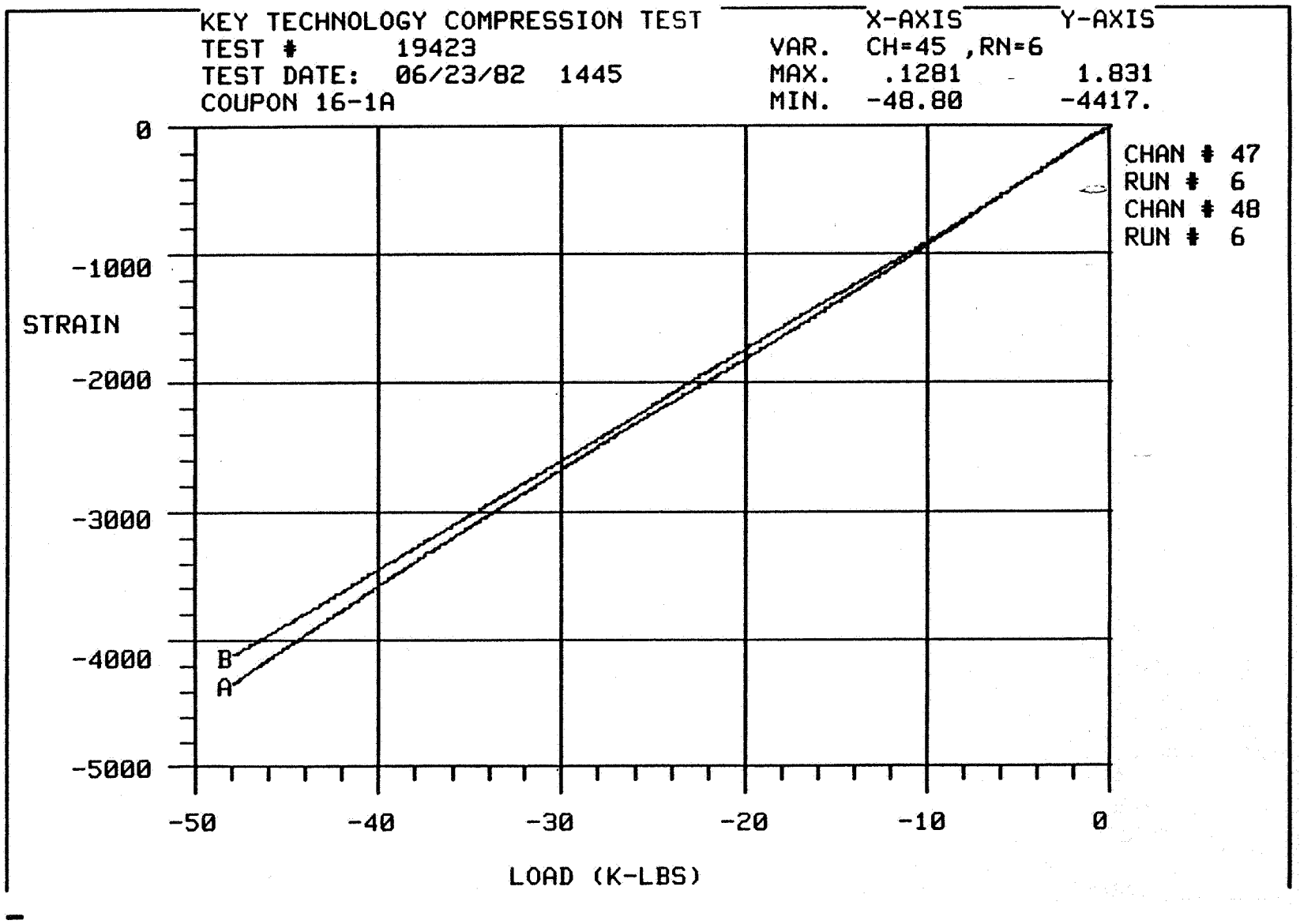
COUPON ID	FAILURE LOAD	GROSS STRESS (KSI)	STRAIN NO1	STRAIN NO2	REMARKS
15-4B	-51.44	-39.070	-4732	-4456	
16-1A	-48.80	-35.562	-4416	-4191	
16-1B	-52.69	-38.436	-5009	-4788	
16-2A	-98.75	-73.651	-9564	-8295	FAILURE AT UPPER EDGE
16-2B	-99.10	-75.826	-10112	-8251	FAILURE AT UPPER EDGE
16-3A	-93.43	-70.827	-7421	-9059	COUPON ROTATED 180° IN FIXTURE

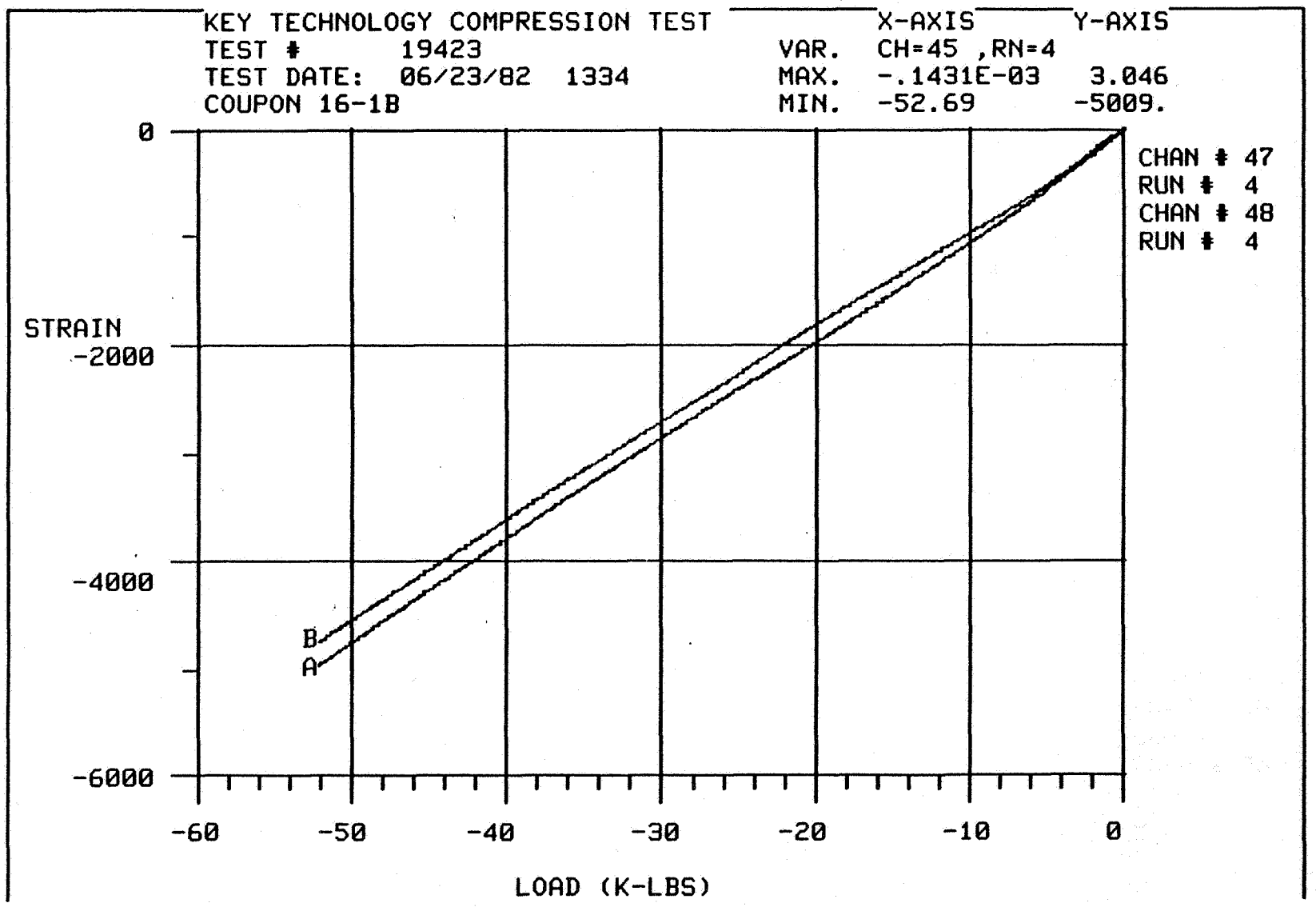
CONTINUED ON E.N. #

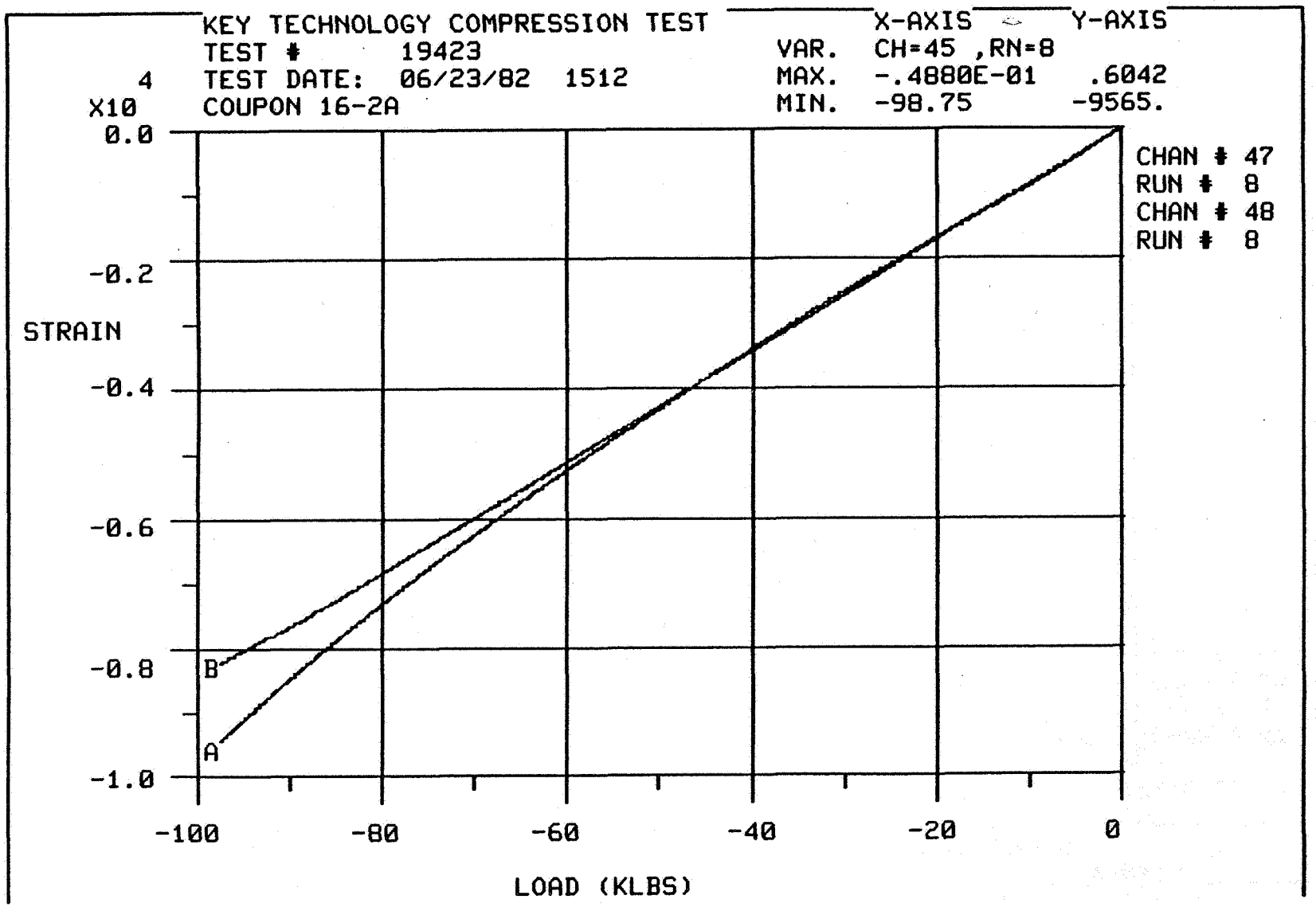
Timothy Gillette

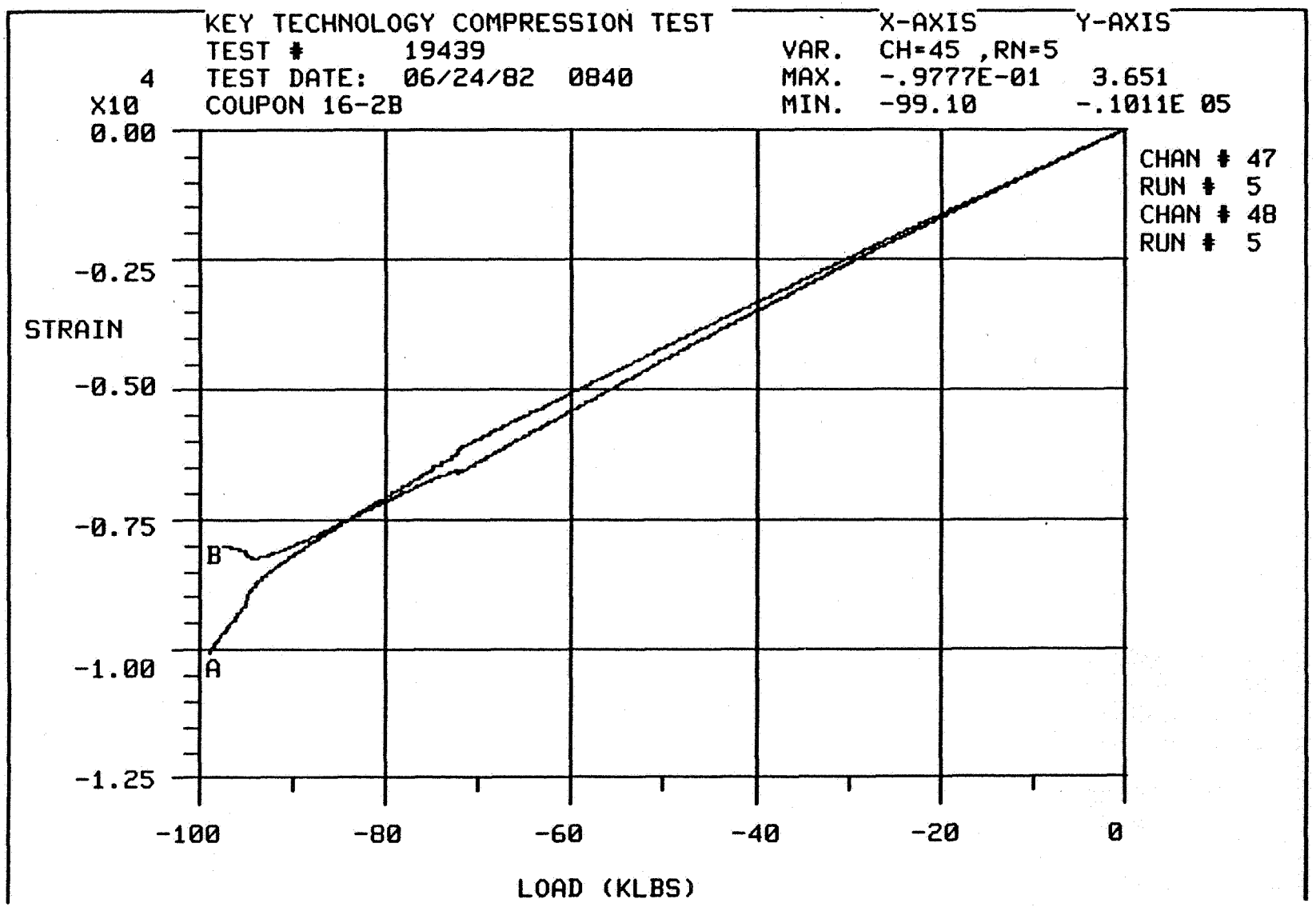
6/24/82

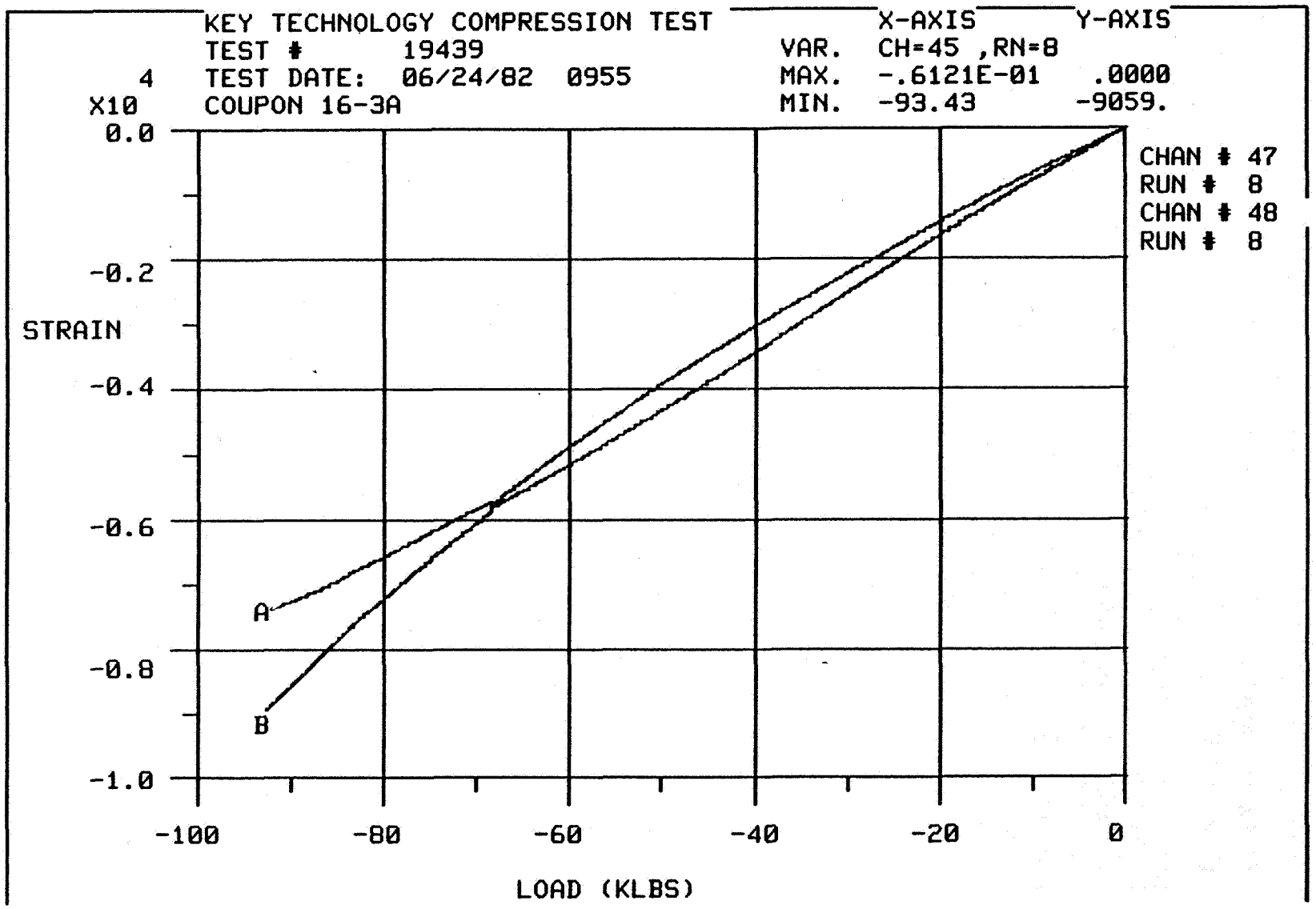

KEY TECHNOLOGY COMPRESSION TEST
TEST # 19423
TEST DATE: 06/23/82 1133
COUPON 15-4B
X-AXIS Y-AXIS
VAR. CH=45 ,RN=2
MAX. -.6304E-02 -.6195
MIN. -51.45 -4732.
CHAN # 47
RUN # 2
CHAN # 48
RUN # 2
0
-1000
-2000
-3000
-4000
-5000
STRAIN
B
A
-60
-50
-40
-30
-20
-10
0
LOAD (K-LBS)


KEY TECHNOLOGY COMPRESSION TEST
TEST # 19423
TEST DATE: 06/23/82 1445
COUPON 16-1A
X-AXIS Y-AXIS
VAR. CH=45 ,RN=6
MAX. .1281 1.831
MIN. -48.80 -4417.
CHAN # 47
RUN # 6
CHAN # 48
RUN # 6
0
-1000
-2000
-3000
-4000
-5000
STRAIN
B
A
-50
-40
-30
-20
-10
0
LOAD (K-LBS)


KEY TECHNOLOGY COMPRESSION TEST
TEST # 19423
TEST DATE: 06/23/82 1334
COUPON 16-1B
X-AXIS
Y-AXIS
VAR. CH=45 ,RN=4
MAX. -.1431E-03 3.046
MIN. -52.69 -5009.
CHAN # 47
RUN # 4
CHAN # 48
RUN # 4
STRAIN
0
-2000
-4000
-6000
B
A
-60
-50
-40
-30
-20
-10
0
LOAD (K-LBS)


KEY TECHNOLOGY COMPRESSION TEST
TEST # 19423
TEST DATE: 06/23/82 1512
COUPON 16-2A
X-AXIS Y-AXIS
VAR. CH=45 ,RN=8
MAX. -.4880E-01 .6042
MIN. -98.75 -9565.
4
X10
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
STRAIN
CHAN # 47
RUN # 8
CHAN # 48
RUN # 8
B
A
-100
-80
-60
-40
-20
0
LOAD (KLBS)


KEY TECHNOLOGY COMPRESSION TEST
TEST # 19439
TEST DATE: 06/24/82 0840
COUPON 16-2B
X-AXIS Y-AXIS
VAR. CH=45 ,RN=5
MAX. -.9777E-01 3.651
MIN. -99.10 -.1011E 05
4
X10
0.00
-0.25
-0.50
-0.75
-1.00
-1.25
STRAIN
B
A
-100
-80
-60
-40
-20
0
LOAD (KLBS)
CHAN # 47
RUN # 5
CHAN # 48
RUN # 5


KEY TECHNOLOGY COMPRESSION TEST
TEST # 19439
TEST DATE: 06/24/82 0955
COUPON 16-3A
X-AXIS Y-AXIS
VAR. CH=45 ,RN=8
MAX. -.6121E-01 .0000
MIN. -93.43 -9059.
4
X10
0.0
-0.2
-0.4
-0.6
-0.8
-1.0
STRAIN
-100
-80
-60
-40
-20
0
LOAD (KLBS)
A
B
CHAN # 47
RUN # 8
CHAN # 48
RUN # 8

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P. SANDIFER	DATE 10/16/82	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11544-39
C. LOOPER		SUBJECT KEY TECHNOLOGY COMPRESSION	REF
MODEL			W.O. EWA

CONTINUED FROM E.N. #

SPECIMEN NO. 15-2-A
DATA CENTRAL TEST NO. 20447 RUN NO. 1
MAX LOAD -33270 LB
MAX STRAIN - SG NO 1 = -17046 90°
MAX STRAIN - SG NO 2 = -16367
AREA = .2508 x 2.005 = .5028 IN^2

SPECIMEN NO. 15-2-B
DATA CENTRAL TEST NO. 20448 RUN NO. 1
MAX LOAD -31567 LB
MAX STRAIN - SG. NO 1 = -15001 90°
MAX STRAIN - SG NO 2 = -15576
AREA = .2538 x 2.001 = .5078 IN^2

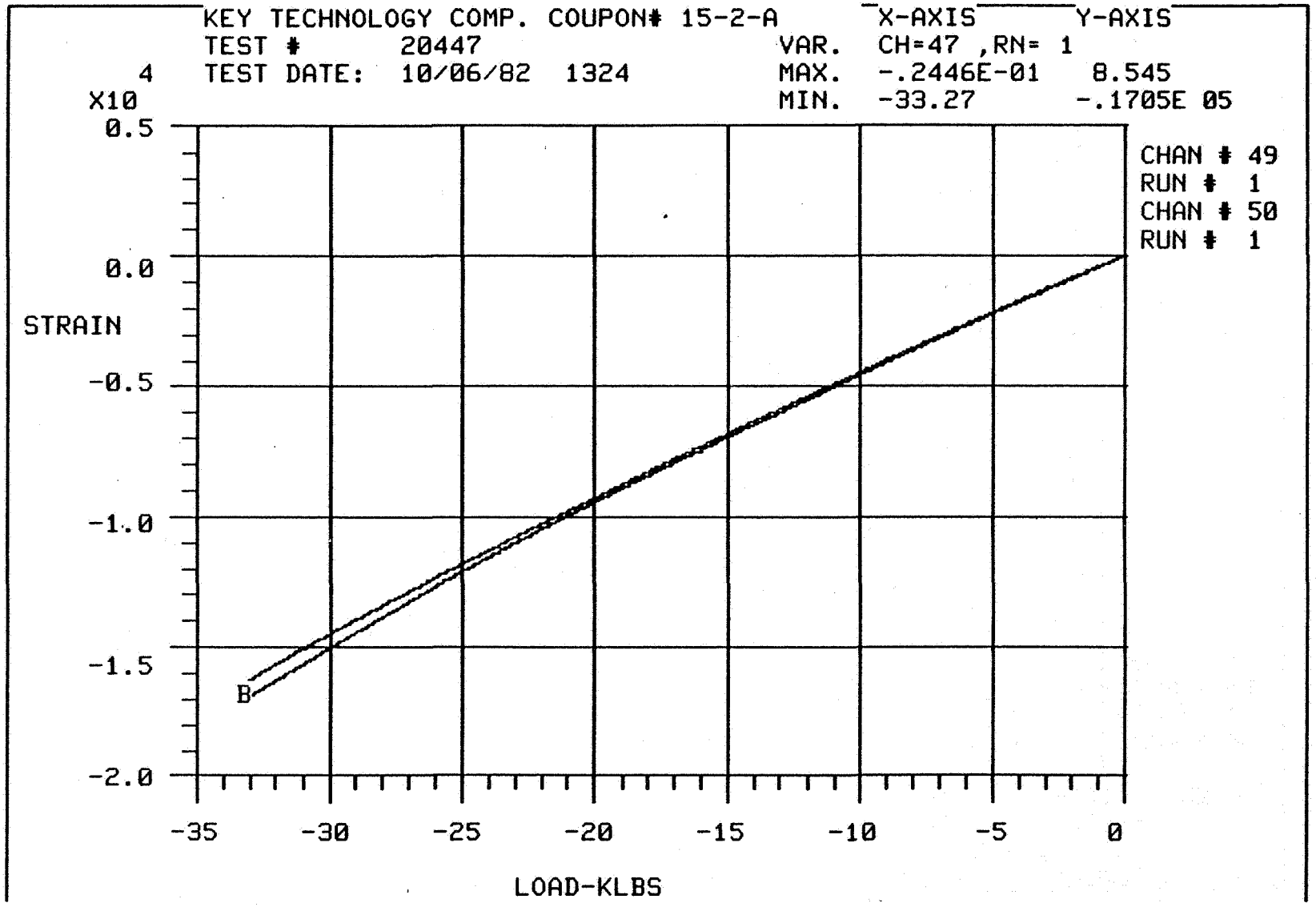
SPECIMEN NO. 34-2-A
DATA CENTRAL TEST NO. 20451 RUN NO. 2
MAX LOAD -52698
MAX STRAIN SG NO. 1 = -12786 0°
MAX STRAIN SG NO. 2 = -13252
AREA = .2504 x 2.003 = .5016 IN^2

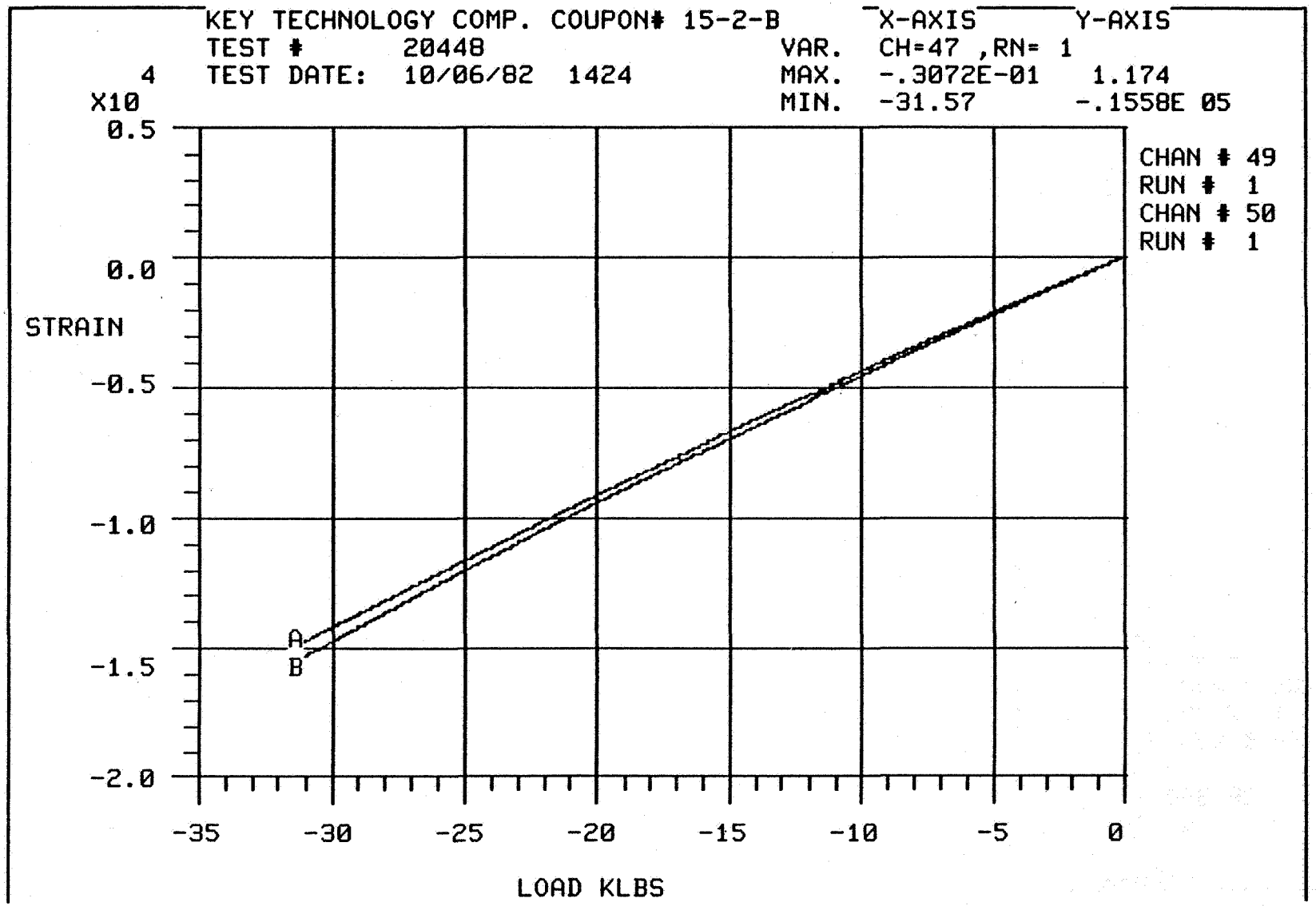
SPECIMEN NO. 34-2-B
DATA CENTRAL TEST NO. 20456 RUN NO. 1
MAX LOAD -52429
MAX STRAIN - SG NO 1 = -12560 0°
MAX STRAIN - SG NO 2 = -12607
AREA = .2523 x 2.008 = .5066 IN^2

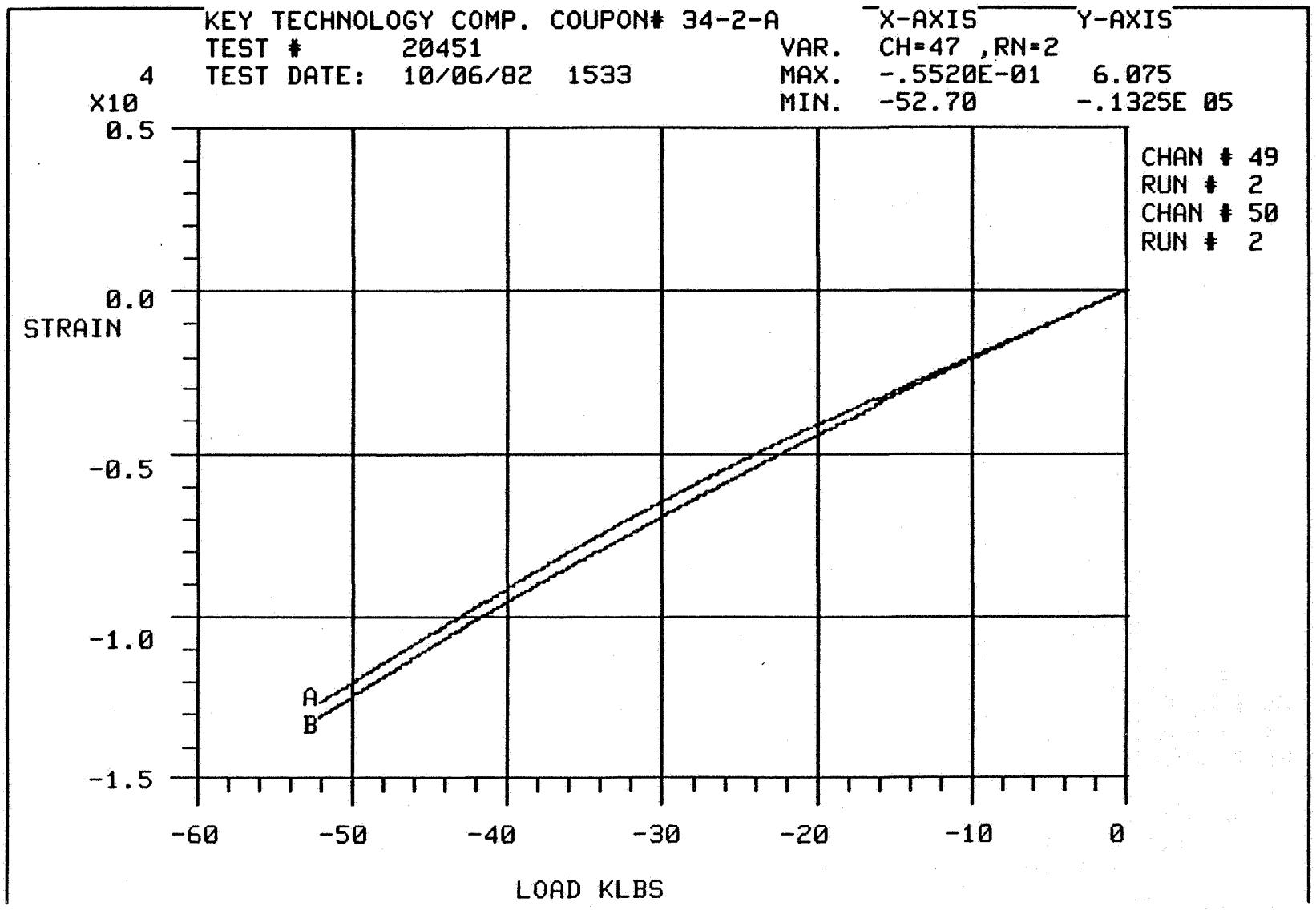
INSTALLATION SHIM WAS .006"

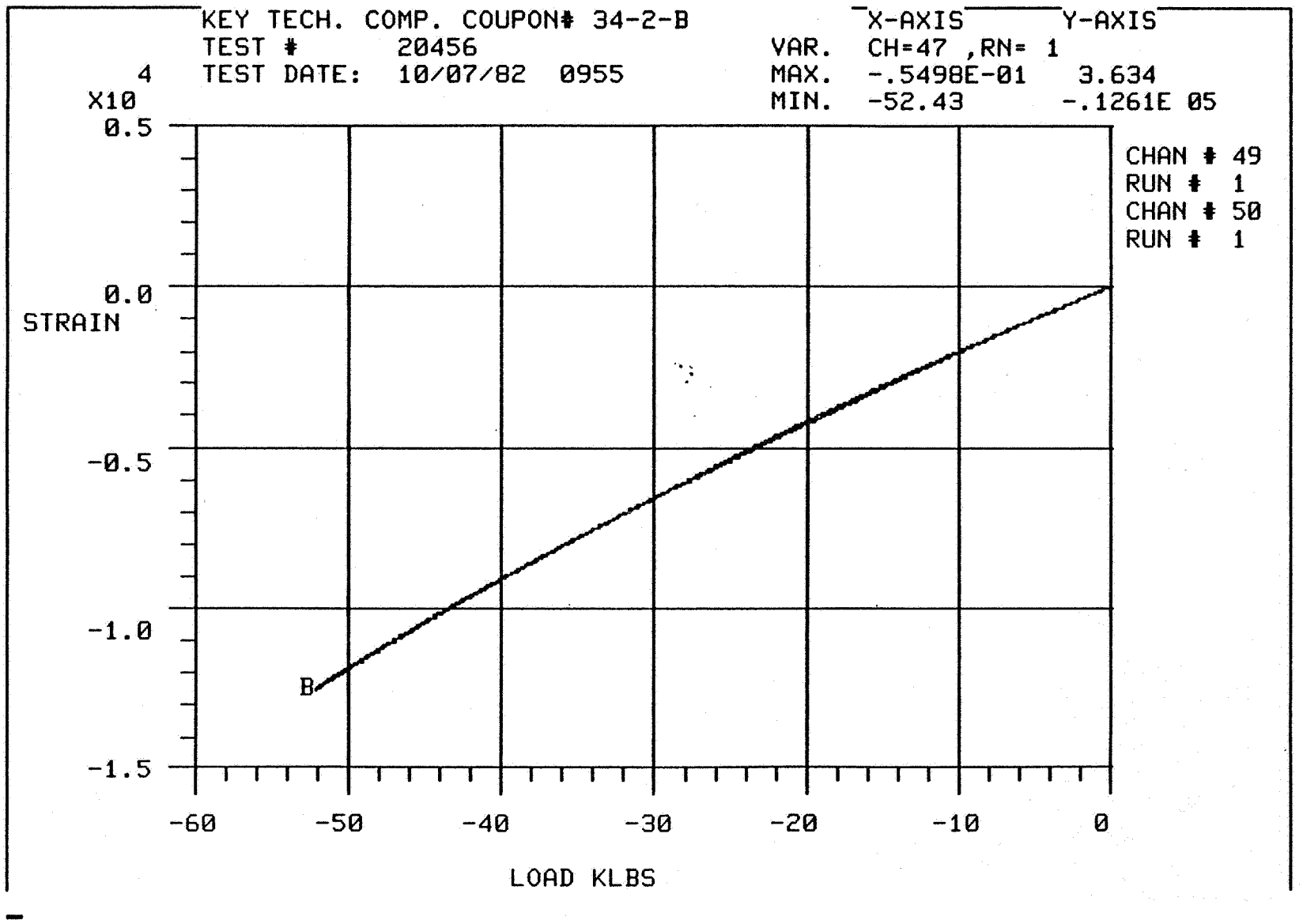
Carl J Looper

CONTINUED ON E.N. #


KEY TECHNOLOGY COMP. COUPON# 15-2-A
TEST # 20447
TEST DATE: 10/06/82 1324
X-AXIS
Y-AXIS
VAR.
CH=47 ,RN= 1
MAX.
-.2446E-01
8.545
MIN.
-33.27
-.1705E 05
4
X10
0.5
0.0
-0.5
-1.0
-1.5
-2.0
STRAIN
-35
-30
-25
-20
-15
-10
-5
0
LOAD-KLBS
B
CHAN # 49
RUN # 1
CHAN # 50
RUN # 1


KEY TECHNOLOGY COMP. COUPON# 15-2-B
TEST # 20448
TEST DATE: 10/06/82 1424
X-AXIS
Y-AXIS
VAR. CH=47 ,RN= 1
MAX. -.3072E-01 1.174
MIN. -31.57 -.1558E 05
4
X10
0.5
0.0
-0.5
-1.0
-1.5
-2.0
STRAIN
CHAN # 49
RUN # 1
CHAN # 50
RUN # 1
A
B
-35
-30
-25
-20
-15
-10
-5
0
LOAD KLBS


KEY TECHNOLOGY COMP. COUPON# 34-2-A
TEST # 20451
TEST DATE: 10/06/82 1533
X-AXIS
Y-AXIS
VAR. CH=47 ,RN=2
MAX. -.5520E-01 6.075
MIN. -52.70 -.1325E 05
4
X10
0.5
0.0
-0.5
-1.0
-1.5
STRAIN
CHAN # 49
RUN # 2
CHAN # 50
RUN # 2
A
B
-60
-50
-40
-30
-20
-10
0
LOAD KLBS

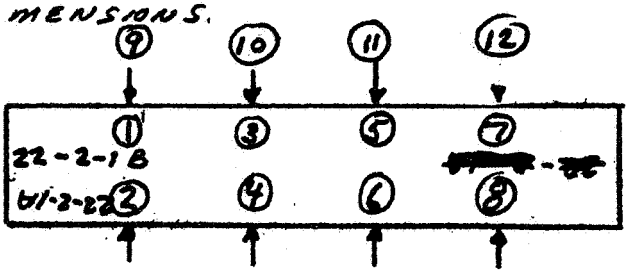

KEY TECH. COMP. COUPON# 34-2-B
TEST # 20456
TEST DATE: 10/07/82 0955
X-AXIS
Y-AXIS
VAR. CH=47 ,RN= 1
MAX. -.5498E-01 3.634
MIN. -52.43 -.1261E 05
4
X10
0.5
0.0
-0.5
-1.0
-1.5
STRAIN
CHAN # 49
RUN # 1
CHAN # 50
RUN # 1
B
-60
-50
-40
-30
-20
-10
0
LOAD KLBS

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P. SANDIFER	10/29/82	LOCKHEED-CALIFORNIA COMPANY ENGINEERS NOTEBOOK	Nº 11544-13
C. LOOPER		KEY TECHNOLOGY	

STRAIN GAGE [redacted] GAGE FACTOR 2.13
OUTPUT 50K REAL = 1127, STRAIN GAGE R = 120Ω

DIMENSIONS.

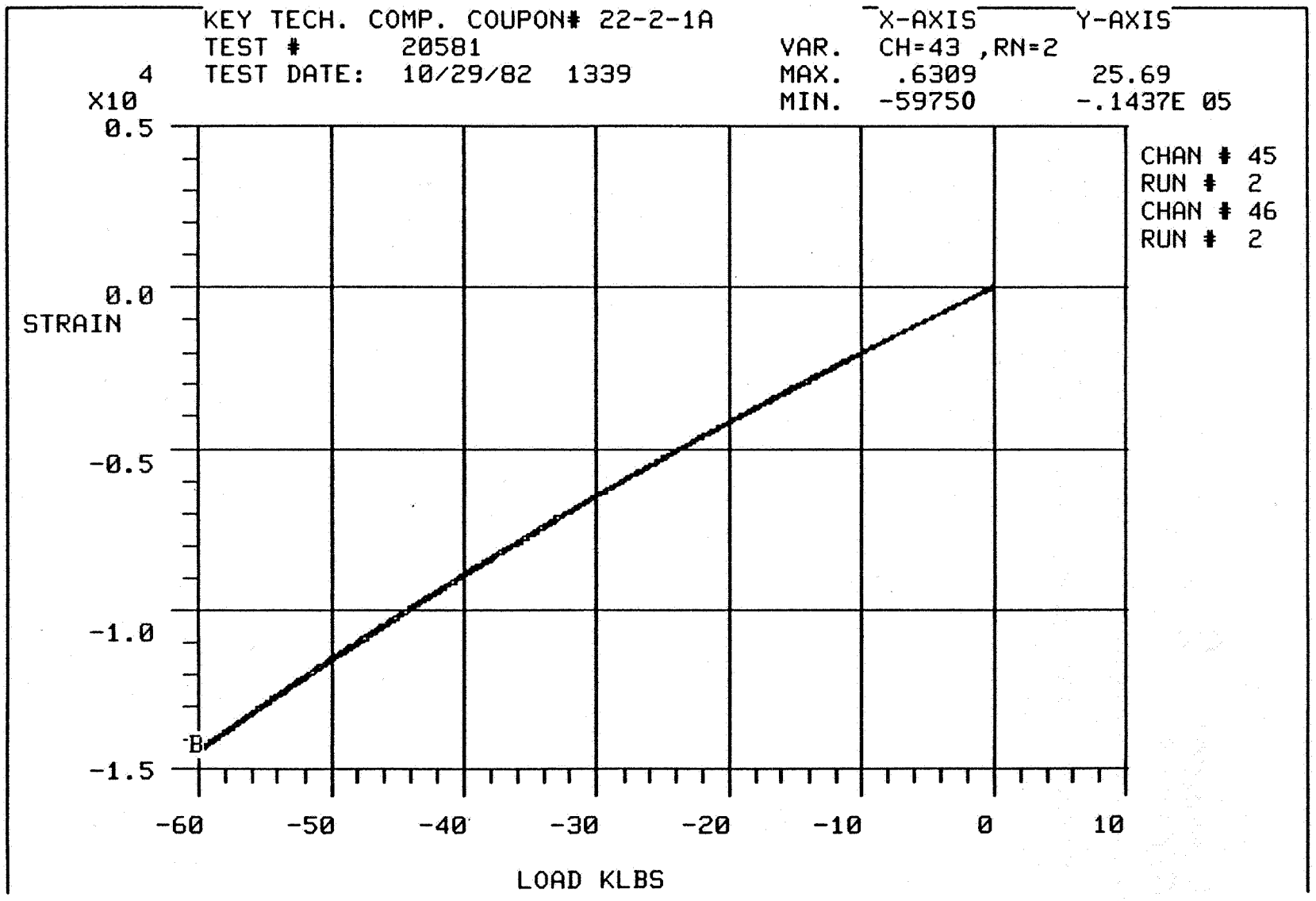


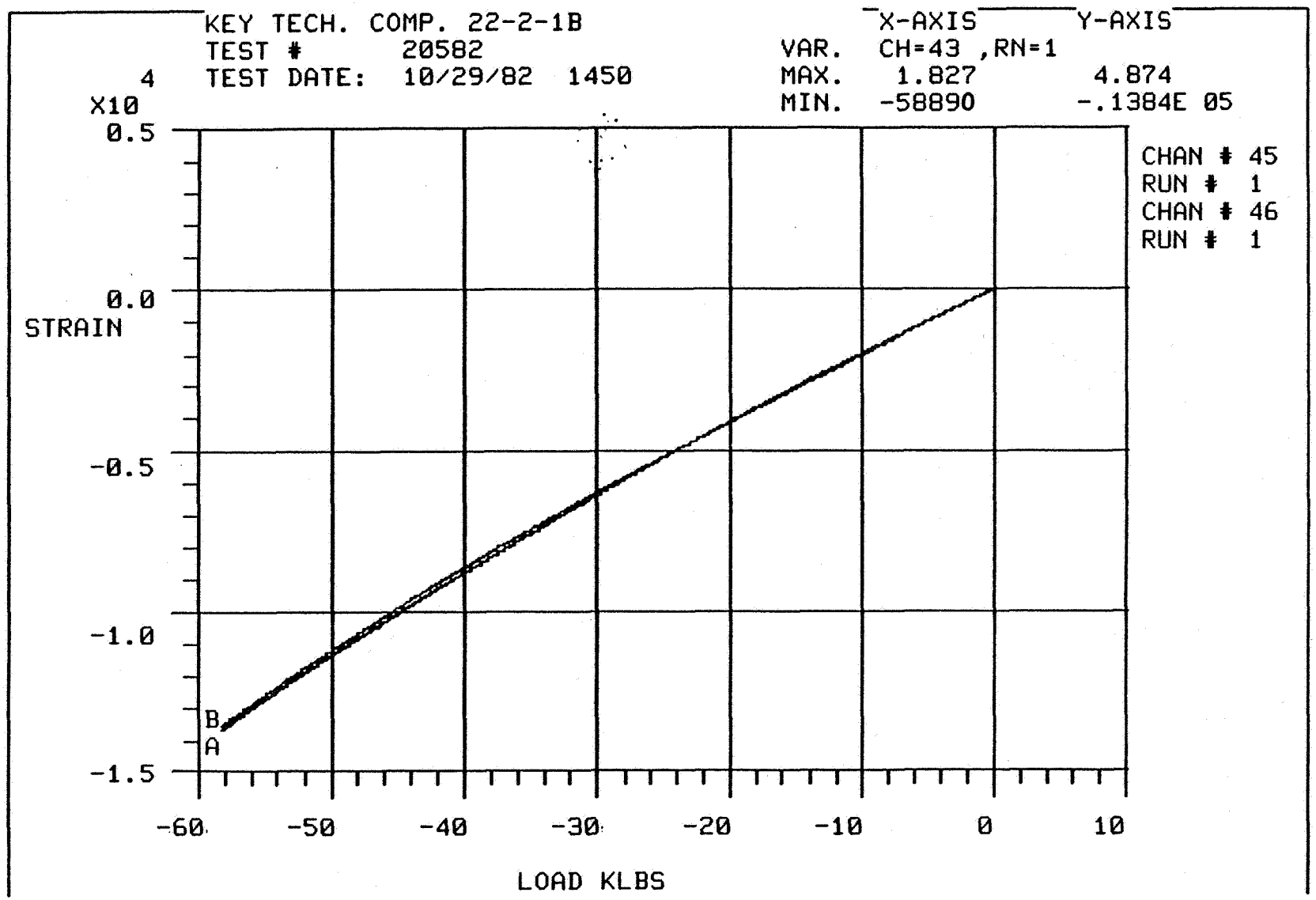
→ 0° orientation

	SPECIMEN 22-2-1A	SPECIMEN 22-2-1B	
1	.2612	.2642	DATA CENTRAL CH.
2	.2682	.2607	Ch. 43 LOAD
3	.2605	.2626	Ch 44 STROKE
4	.2631	.2595	Ch 45 SG #1
5	.2611	.2623	Ch 46 SG #2
6	.2640	.2605	
7	.2602	.2637	
8	.2648	.2594	
AVE	.2623	.2616	
9	2.002	2.005	
10	2.002	2.002	
11	2.002	2.002	
12	2.002	2.001	
AVE	2.002	2.002	
AREA	.525	.524	
DC TEST NO	20581	20582	
RUN NO	2	1	
MAX LOAD	-59750	-58887	
SG NO. 1	-14254	-13888	
SG NO. 2	-14374	-13691	
SHIM	.006	.006	

Carl J Looper

DC = DATA CENTRAL, SG = STRAIN GAGE


KEY TECH. COMP. COUPON# 22-2-1A
TEST # 20581
TEST DATE: 10/29/82 1339
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=2
MAX. .6309 25.69
MIN. -59750 -.1437E 05
4
X10
0.5
0.0
-0.5
-1.0
-1.5
STRAIN
B
CHAN # 45
RUN # 2
CHAN # 46
RUN # 2
-60
-50
-40
-30
-20
-10
0
10
LOAD KLBS


KEY TECH. COMP. 22-2-1B
TEST # 20582
TEST DATE: 10/29/82 1450
X-AXIS
Y-AXIS
VAR. CH=43 ,RN=1
MAX. 1.827 4.874
MIN. -58890 -.1384E 05
4
X10
0.5
0.0
-0.5
-1.0
-1.5
STRAIN
CHAN # 45
RUN # 1
CHAN # 46
RUN # 1
B
A
-60
-50
-40
-30
-20
-10
0
10
LOAD KLBS

APPENDIX B4

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LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED CORPORATION
ENGINEERS NOTEBOOK

№ 11546-46

FROM: PAUL SANDIFER

DATE: 6 2 / 29 / 82

SUBJECT: KEY TECHNOLOGY ±45 DEGREE COUPONS

±45° TENSION
ASU 13502

section	121	122	123	17-4	17-5
1	0.0616	0.0617	0.0627	0.0616	0.0628
2	0.0612	0.0638	0.0630	0.0628	0.0641
3	0.0617	0.0621	0.0619	0.0627	0.0611
4	0.0601	0.0617	0.0629	0.0615	0.0603
5	0.0632	0.0629	0.0627	0.0626	0.0622
6	0.0616	0.0614	0.0619	0.0613	0.0618
AVE	0.0615	0.0623	0.0625	0.0621	0.0620
7	1.0020	1.0012	1.0019	1.0020	0.999
8	1.0021	1.0015	1.0018	1.0013	1.0003
9	1.0028	1.0017	1.0018	1.0013	1.0016
AVE	1.0023	1.0015	1.0018	1.0015	1.0003
AREA	0.0616	0.0624	0.0626	0.0622	0.0620
TENSILE	19520/2	19520/2	19520/4	19520/5	19520/6
LOAD	1 183.8	1 183.5	1 181.9	1 122.5	1 122.7
LBS	8.117	8.013	7.987	8.039	8.047
KUSI	742	996	1992	1991	1594
SCAN					
OP	45 DEGREE				

69:3:51 GT 4000 #/mat
70:4:53 EL 4000 #/mat
GF_L = 2.075
GF_T = 2.095

Br .12x10^6
GF x (Br 12+50K)

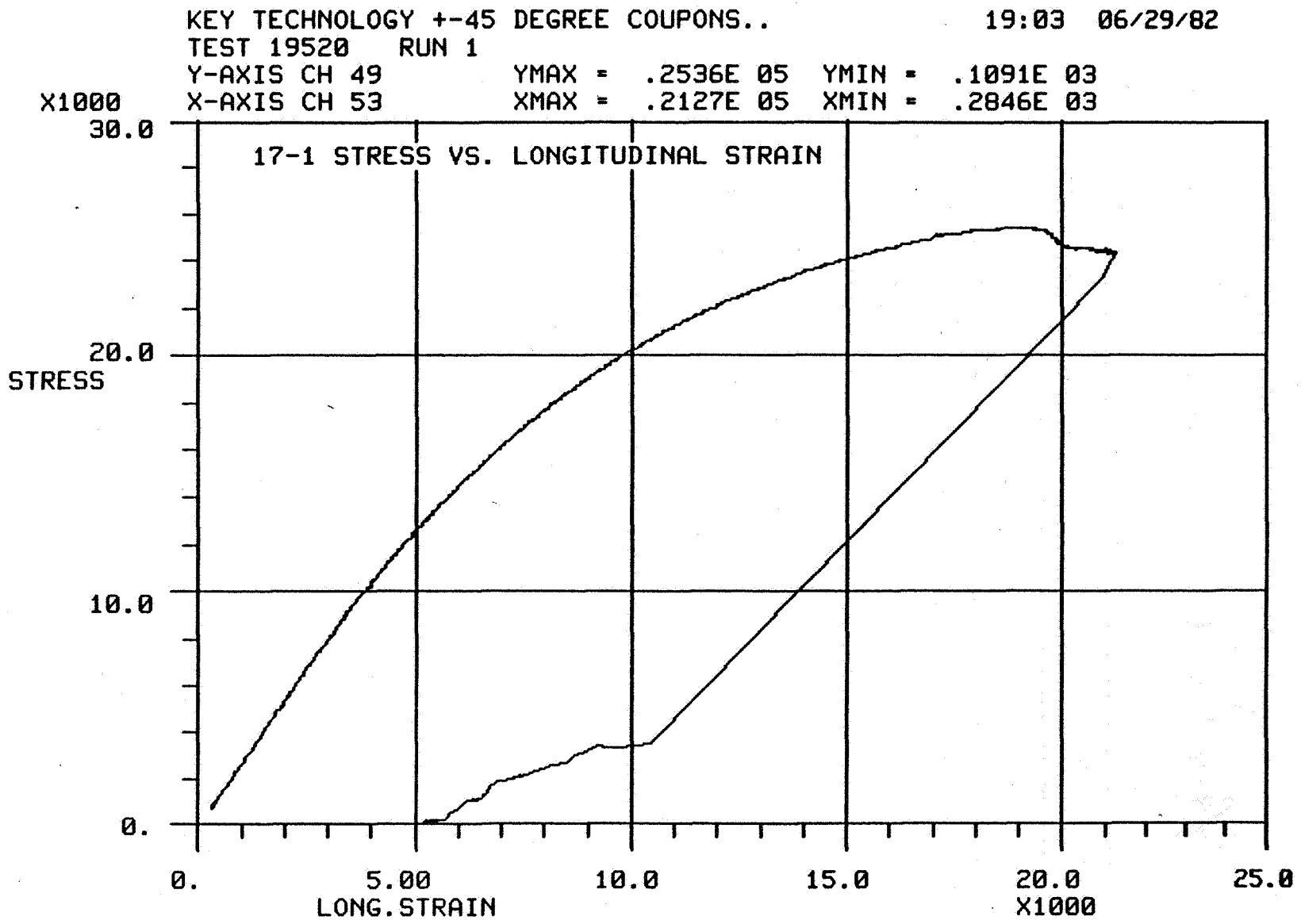
E_T = SEE ABOVE

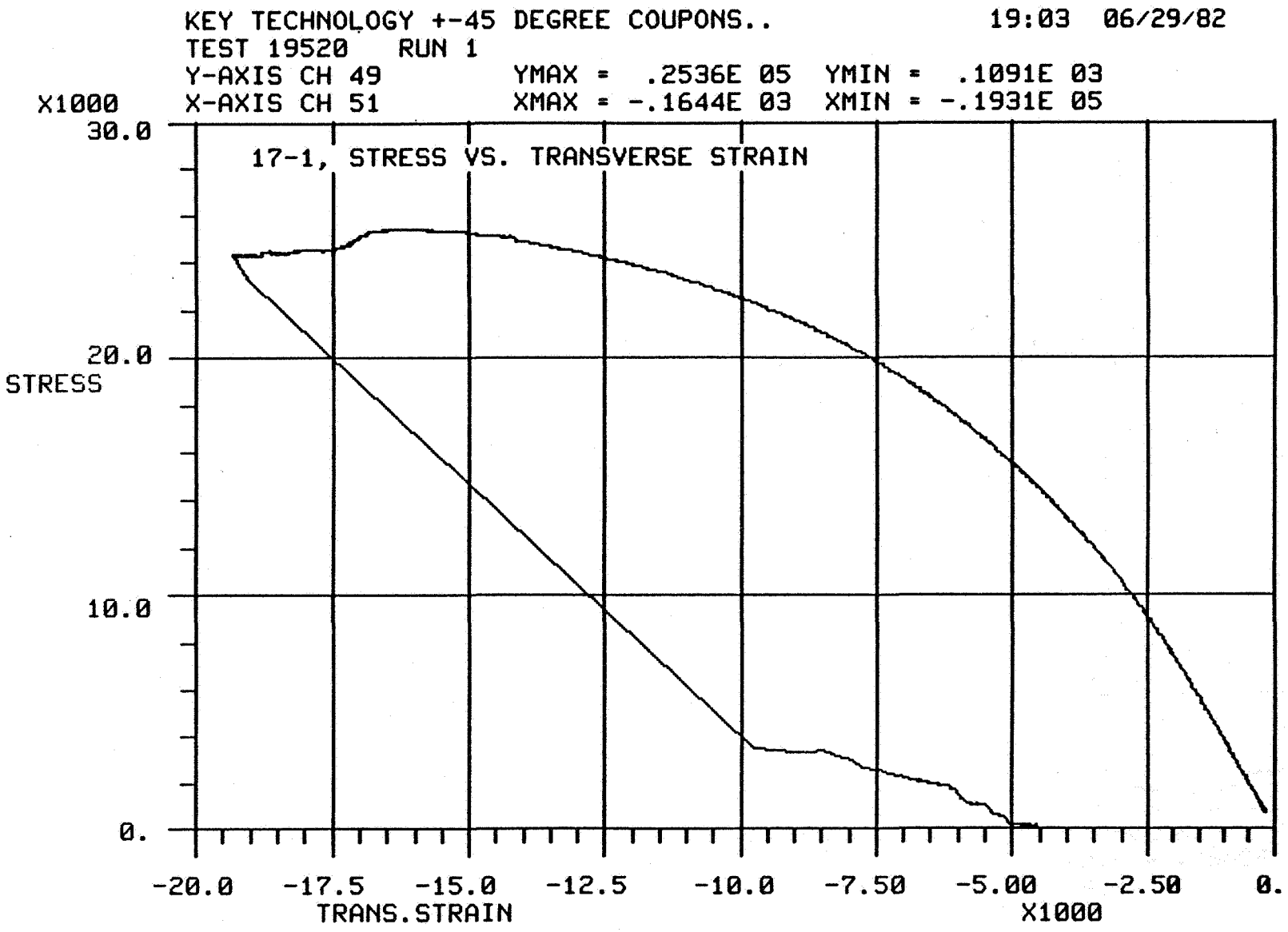
E_L = SEE ABOVE

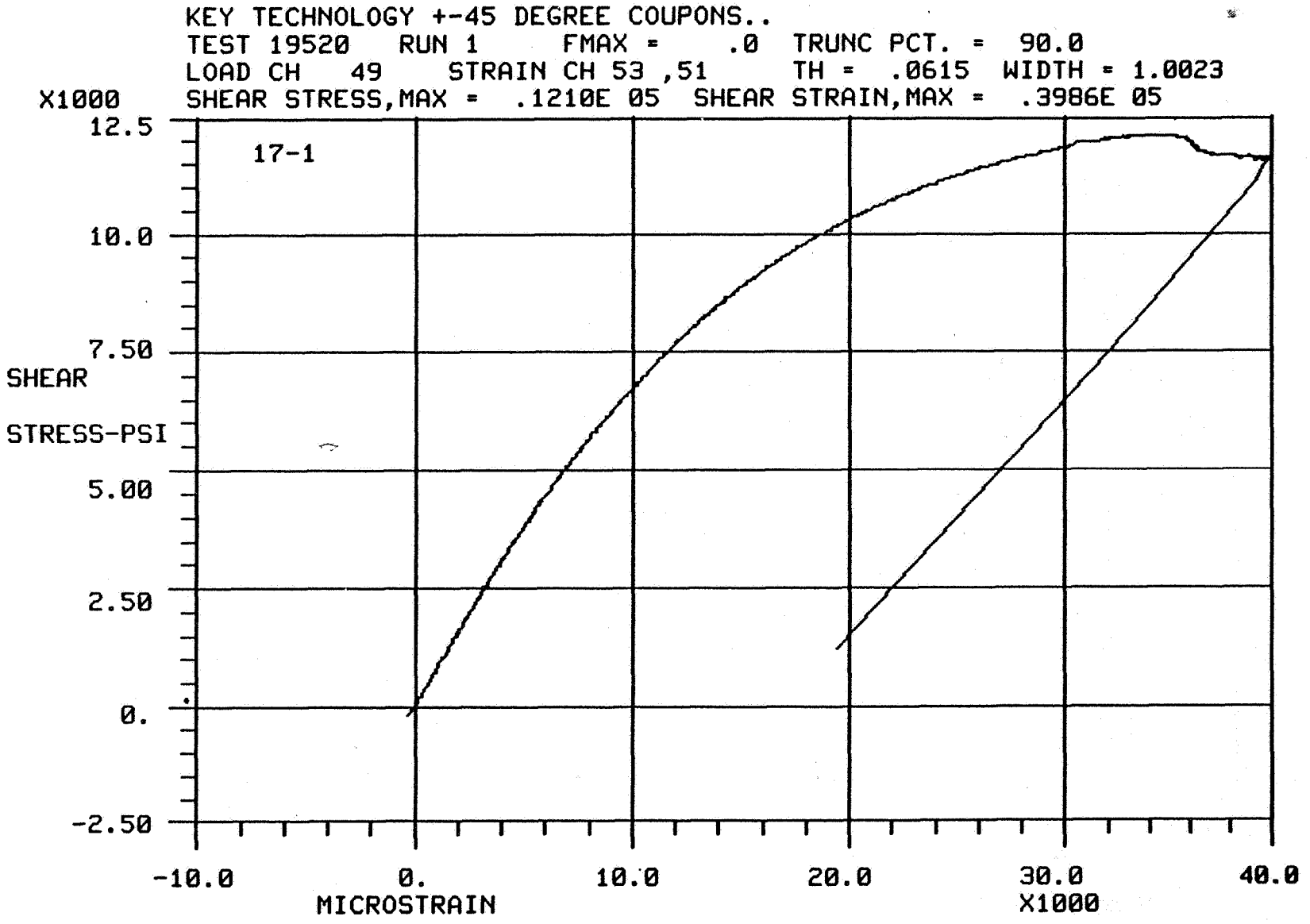
5	2	1
		17-N
4	6	6
7	8	7

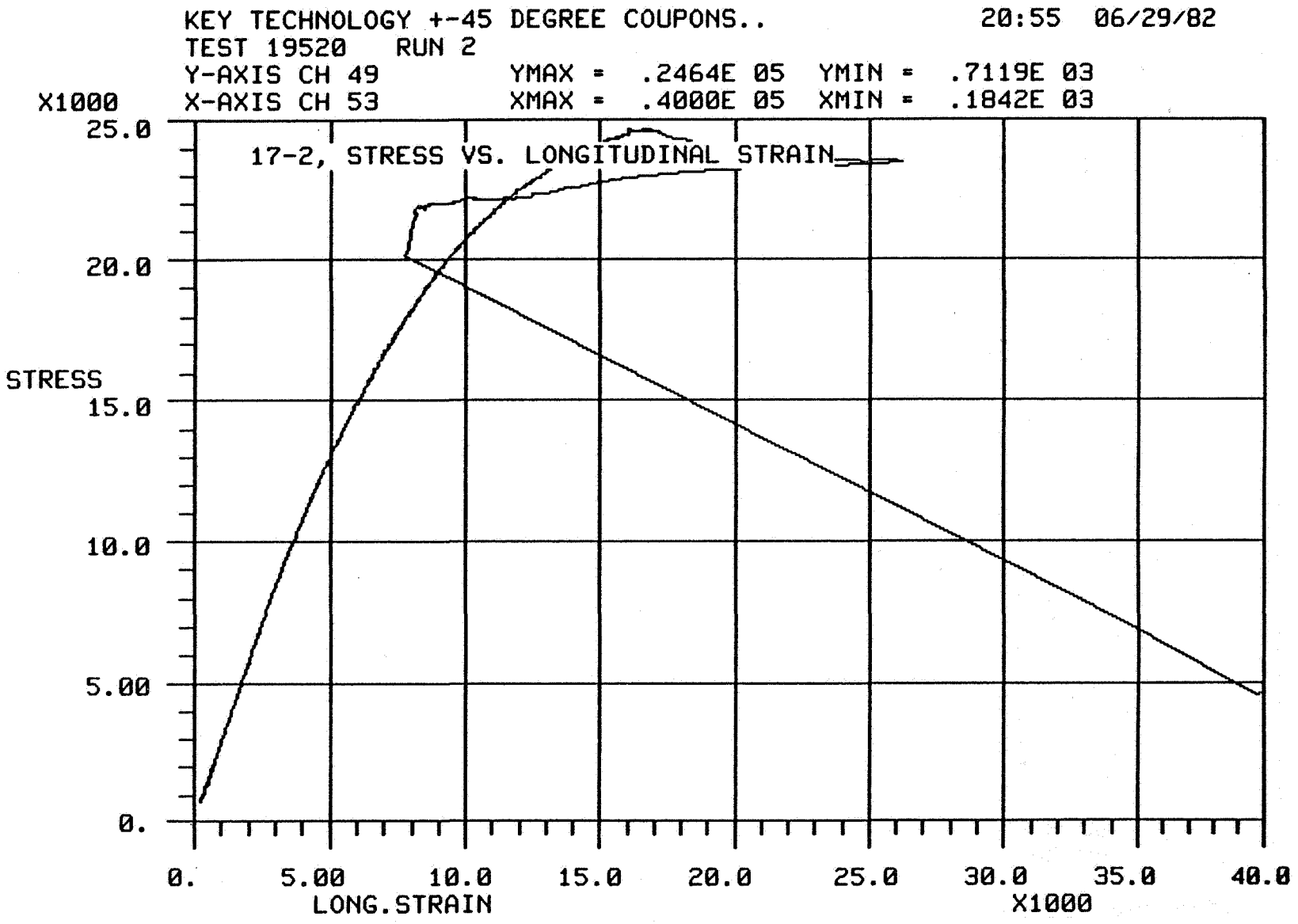
E_L
E_T

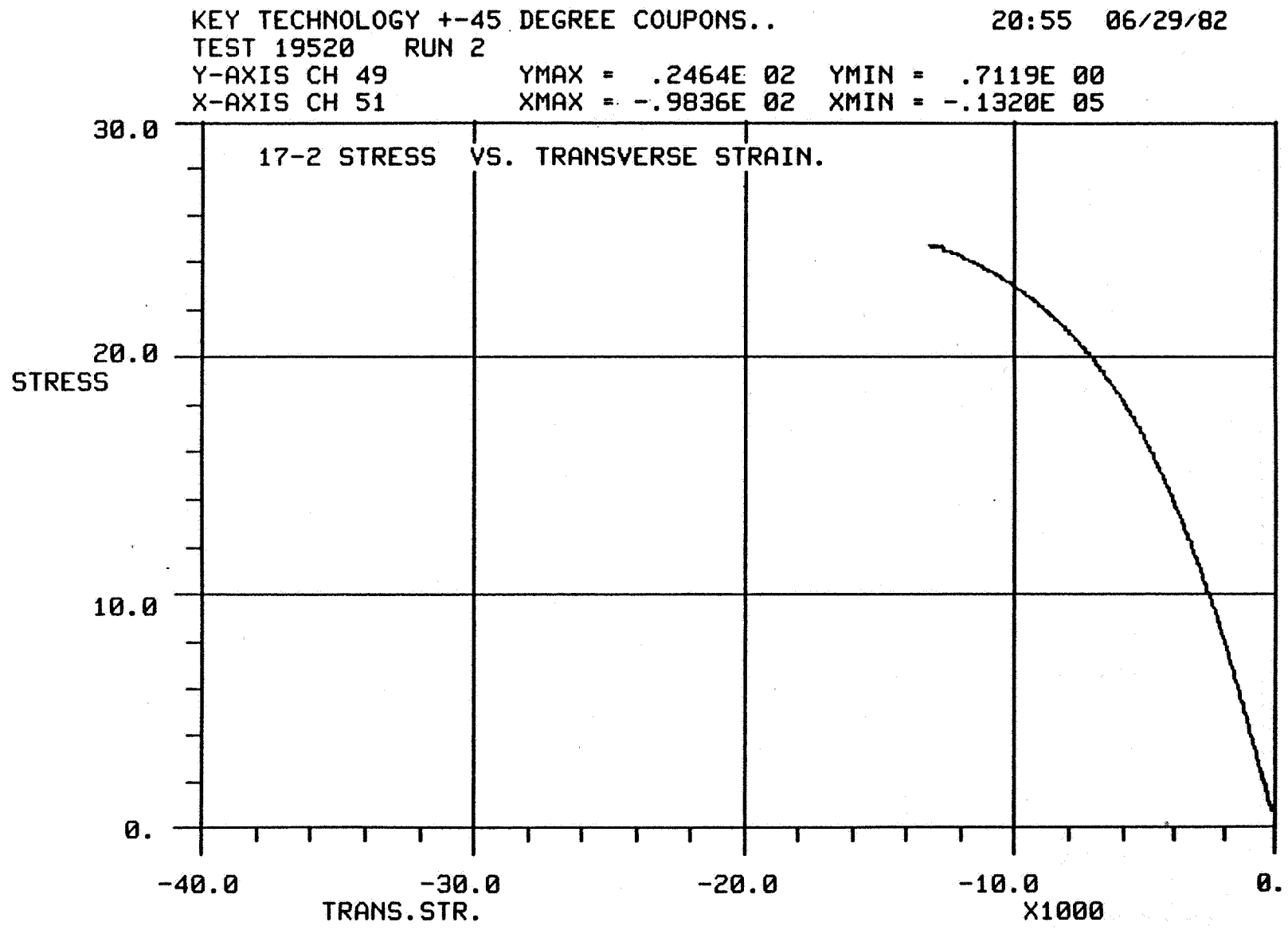
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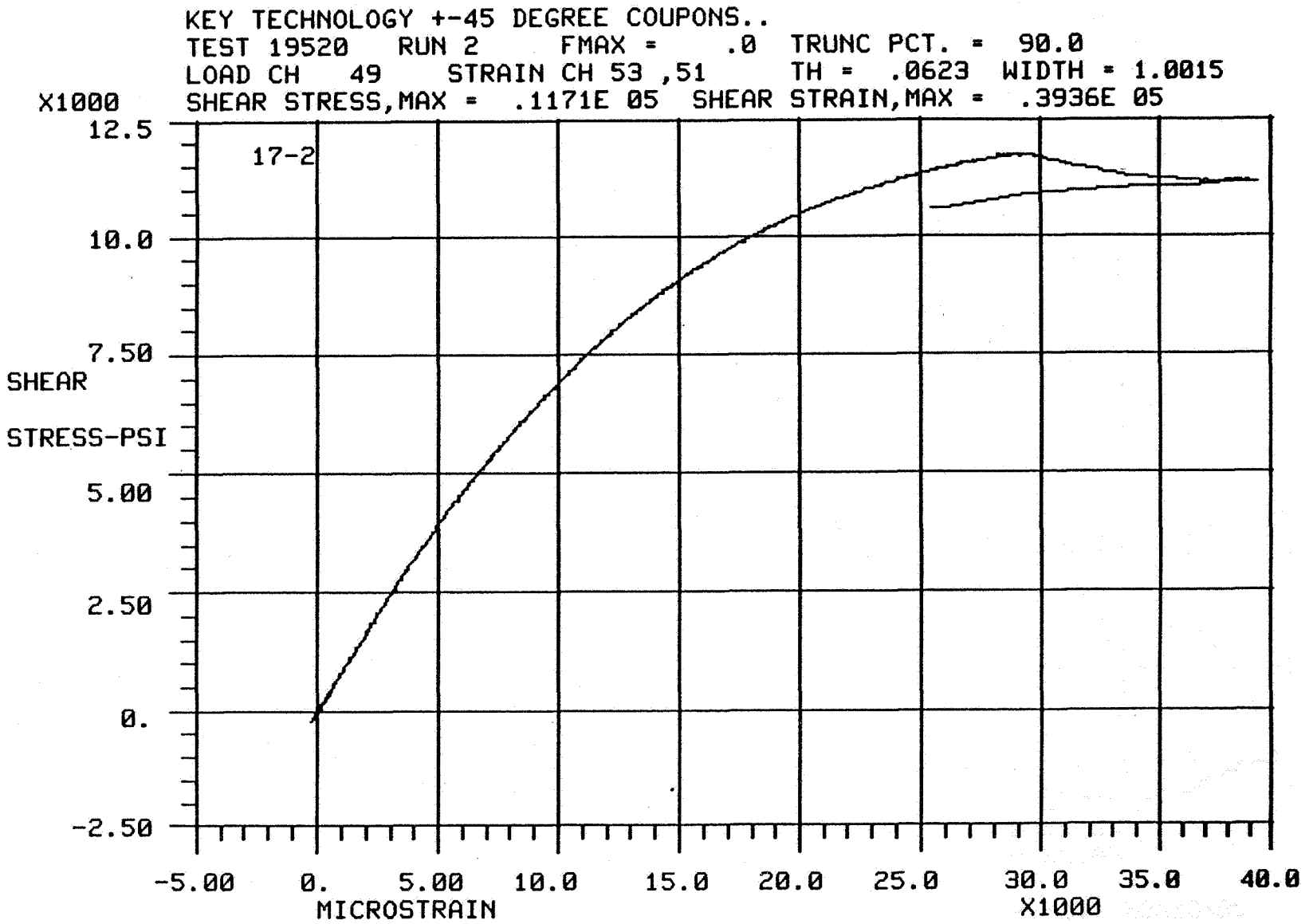

KEY TECHNOLOGY +-45 DEGREE COUPONS..
19:03 06/29/82
TEST 19520 RUN 1
Y-AXIS CH 49
YMAX = .2536E 05
YMIN = .1091E 03
X-AXIS CH 53
XMAX = .2127E 05
XMIN = .2846E 03
17-1 STRESS VS. LONGITUDINAL STRAIN
X1000
30.0
20.0
10.0
0.
STRESS
0.
5.00
10.0
15.0
20.0
25.0
LONG.STRAIN
X1000

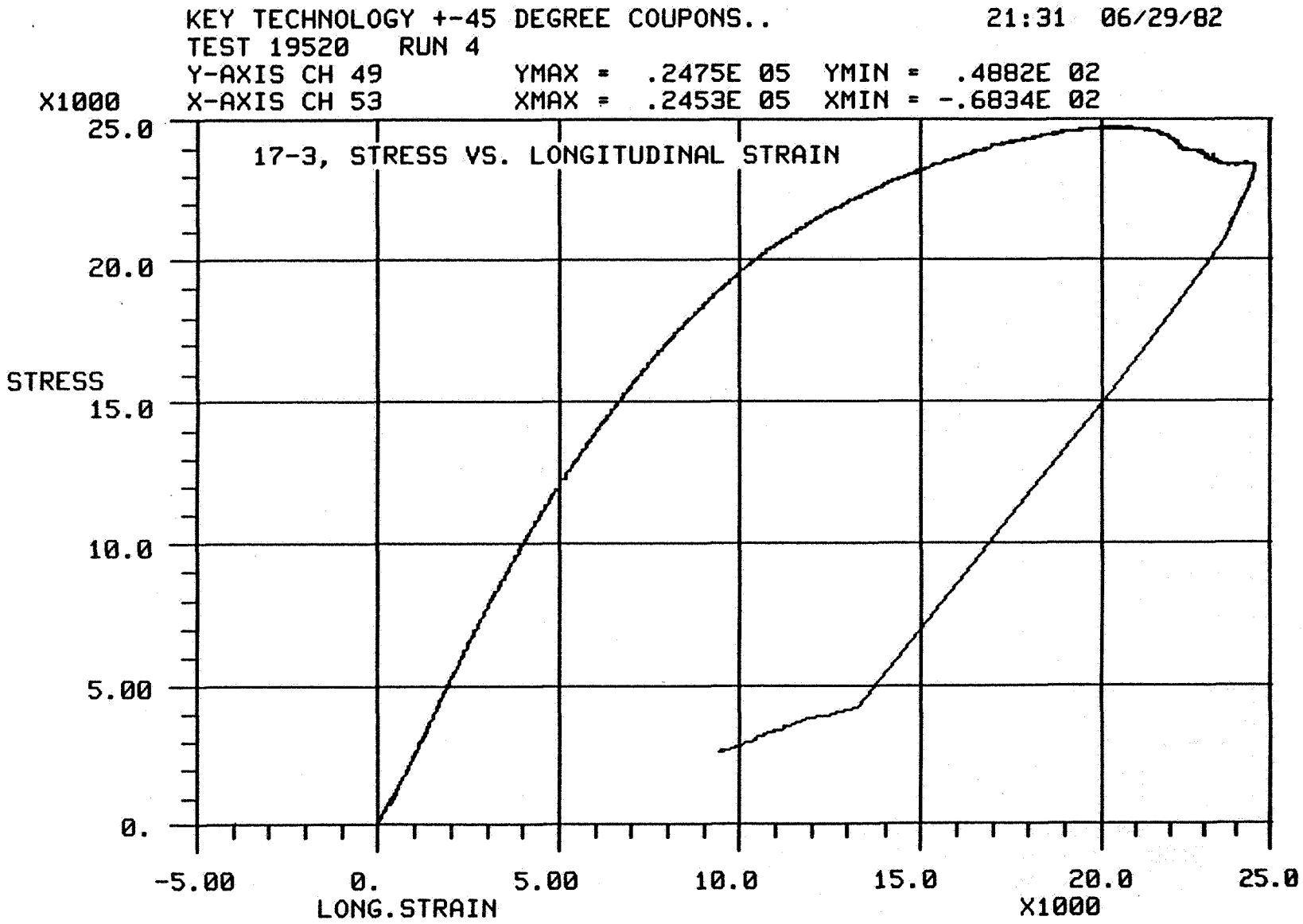

KEY TECHNOLOGY +-45 DEGREE COUPONS..
19:03 06/29/82
TEST 19520 RUN 1
Y-AXIS CH 49
YMAX = .2536E 05
YMIN = .1091E 03
X-AXIS CH 51
XMAX = -.1644E 03
XMIN = -.1931E 05
X1000
30.0
17-1, STRESS VS. TRANSVERSE STRAIN
20.0
STRESS
10.0
0.
-20.0
-17.5
-15.0
-12.5
-10.0
-7.50
-5.00
-2.50
0.
TRANS.STRAIN
X1000

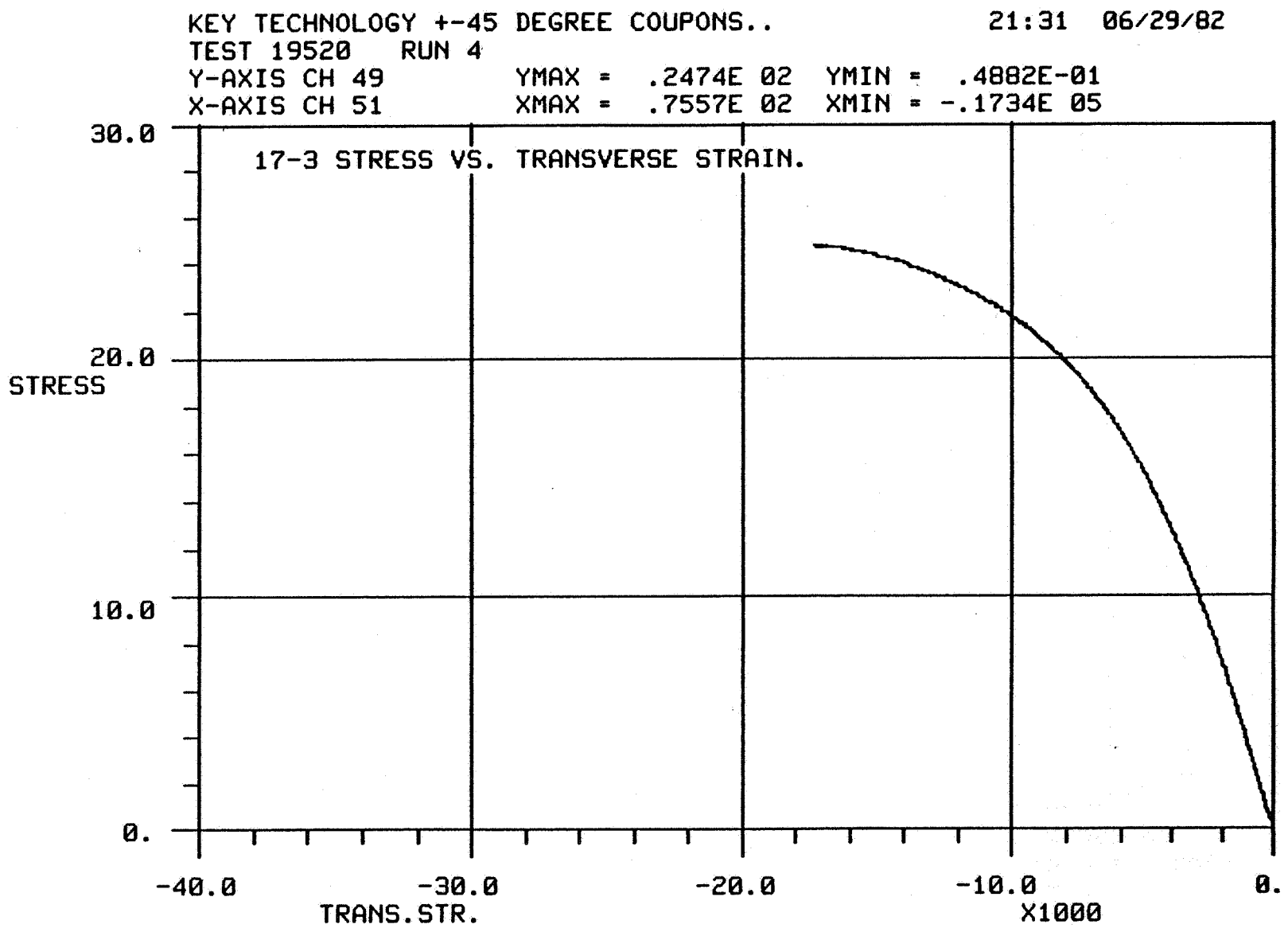

KEY TECHNOLOGY +-45 DEGREE COUPONS..
TEST 19520 RUN 1 FMAX = .0 TRUNC PCT. = 90.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0615 WIDTH = 1.0023
X1000 SHEAR STRESS,MAX = .1210E 05 SHEAR STRAIN,MAX = .3986E 05
17-1
12.5
10.0
7.50
SHEAR
STRESS-PSI
5.00
2.50
0.
-2.50
-10.0
0.
10.0
20.0
30.0
40.0
MICROSTRAIN
X1000

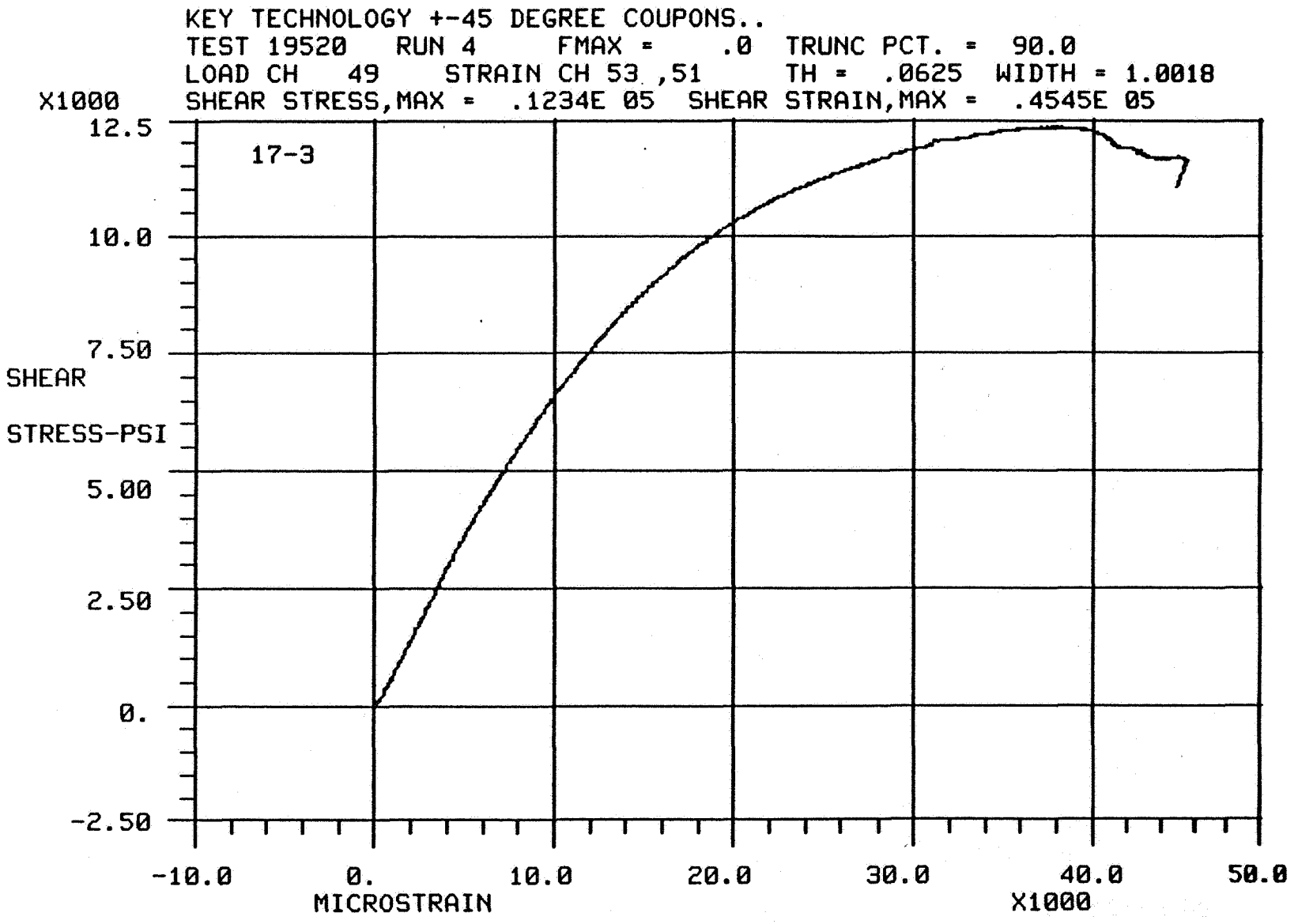

KEY TECHNOLOGY +-45 DEGREE COUPONS..
20:55 06/29/82
TEST 19520 RUN 2
Y-AXIS CH 49
YMAX = .2464E 05
YMIN = .7119E 03
X-AXIS CH 53
XMAX = .4000E 05
XMIN = .1842E 03
X1000
17-2, STRESS VS. LONGITUDINAL STRAIN
STRESS
25.0
20.0
15.0
10.0
5.00
0.
0.
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
LONG.STRAIN
X1000

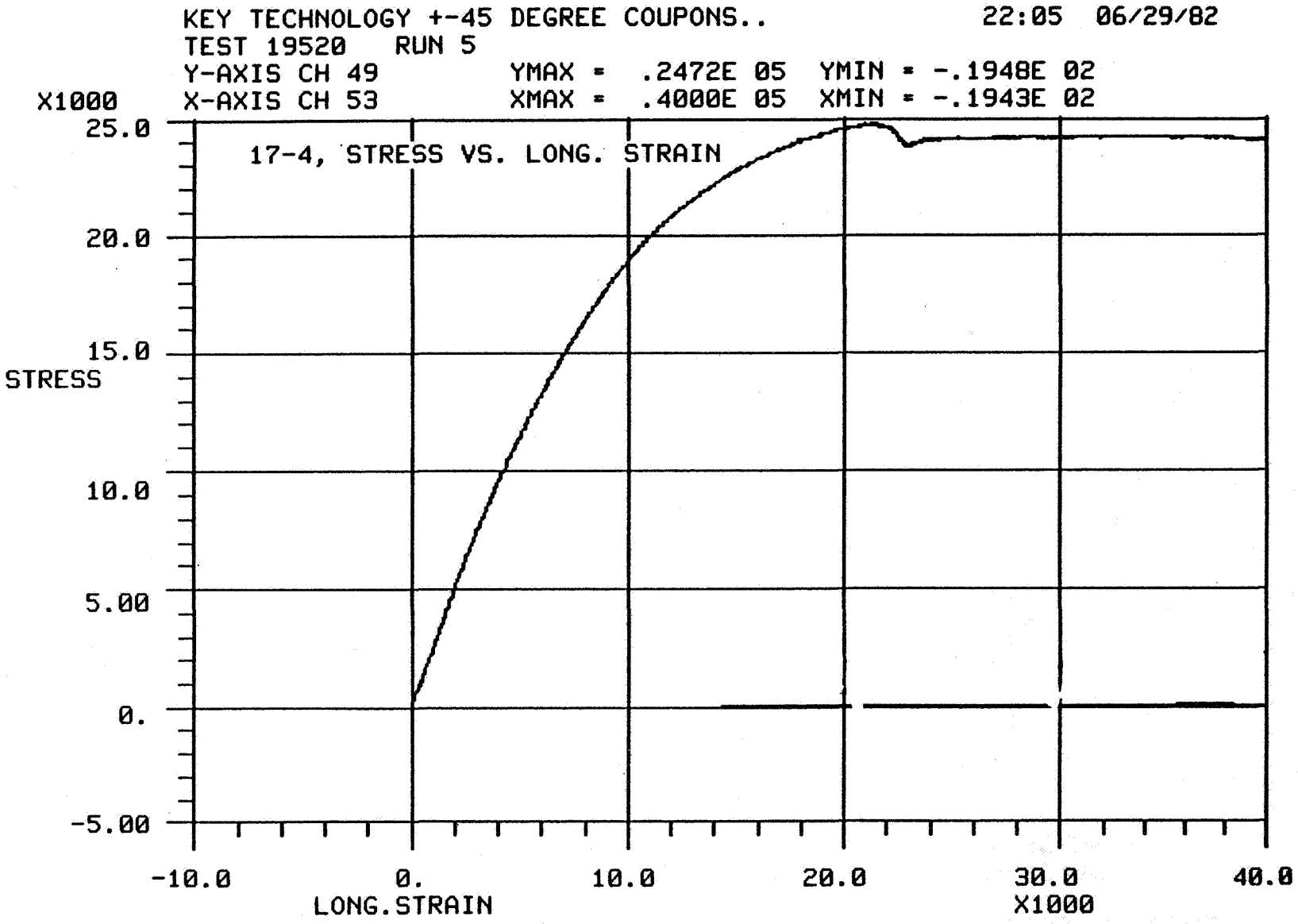

KEY TECHNOLOGY +-45 DEGREE COUPONS..
20:55 06/29/82
TEST 19520 RUN 2
Y-AXIS CH 49 YMAX = .2464E 02 YMIN = .7119E 00
X-AXIS CH 51 XMAX = -.9836E 02 XMIN = -.1320E 05
17-2 STRESS VS. TRANSVERSE STRAIN.
30.0
20.0
10.0
0.
STRESS
-40.0
-30.0
-20.0
-10.0
0.
TRANS.STR.
X1000

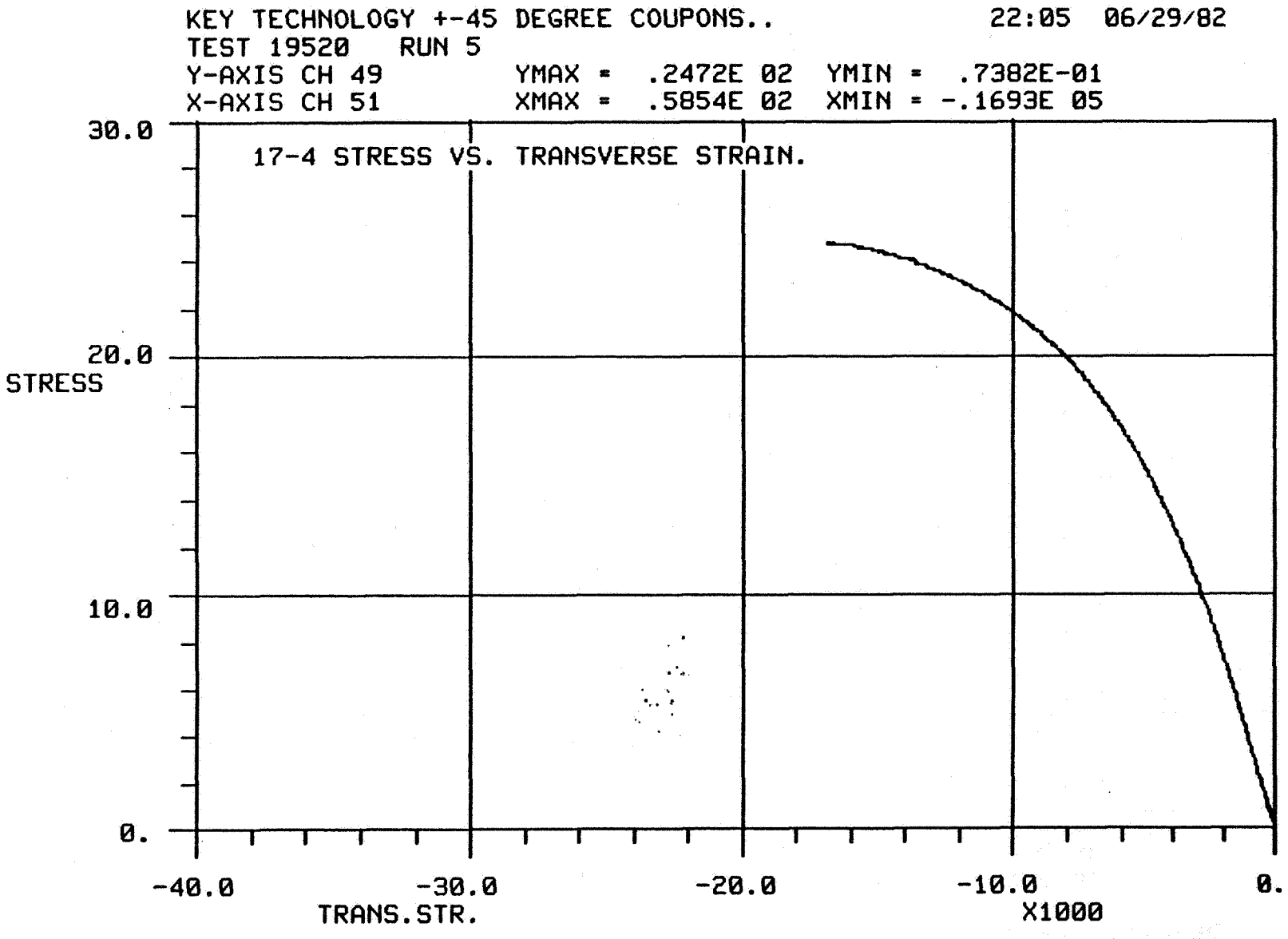

KEY TECHNOLOGY +-45 DEGREE COUPONS..
TEST 19520 RUN 2 FMAX = .0 TRUNC PCT. = 90.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0623 WIDTH = 1.0015
X1000 SHEAR STRESS,MAX = .1171E 05 SHEAR STRAIN,MAX = .3936E 05
17-2
12.5
10.0
7.50
SHEAR
STRESS-PSI
5.00
2.50
0.
-2.50
-5.00
0.
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
MICROSTRAIN
X1000

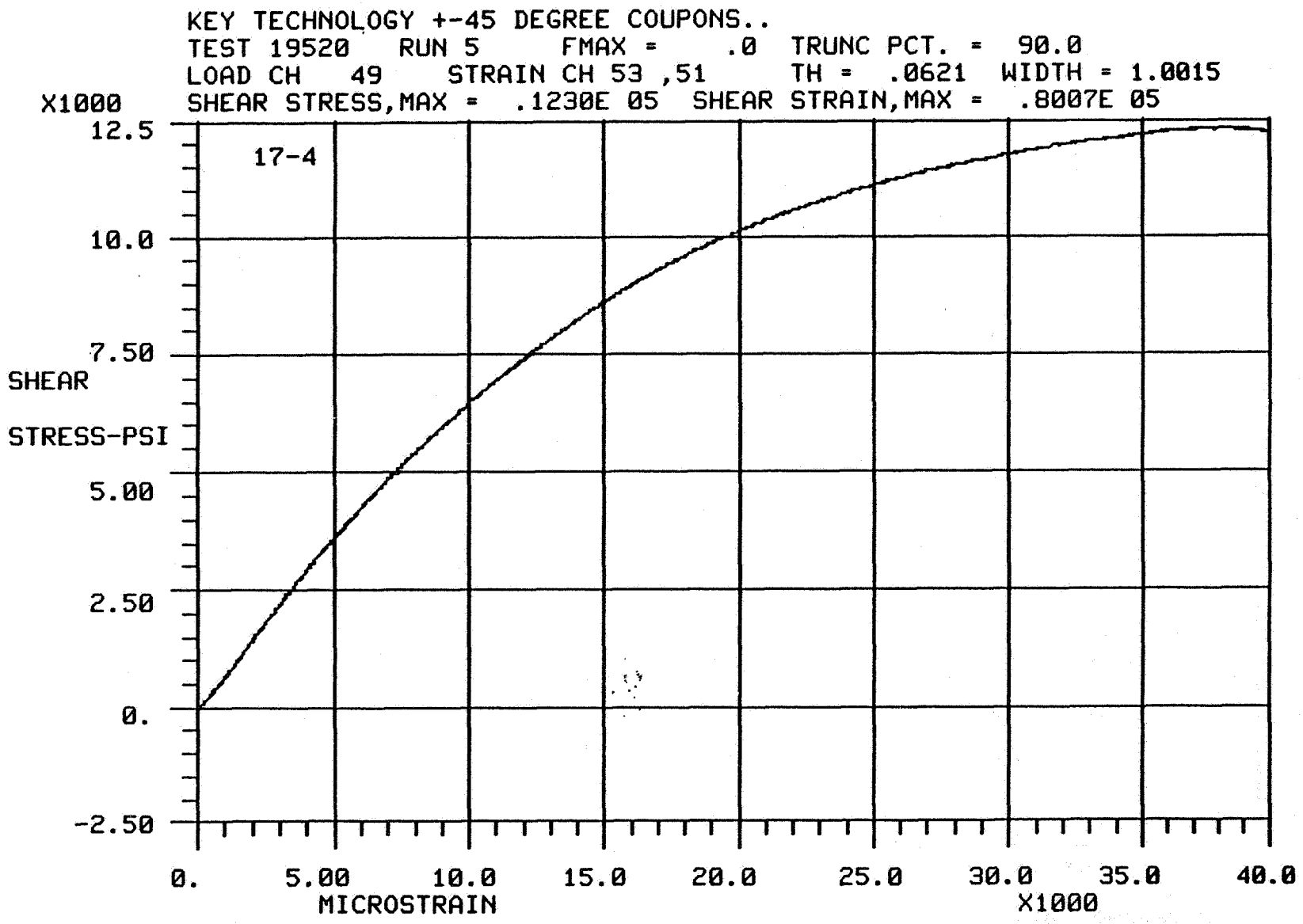

KEY TECHNOLOGY +-45 DEGREE COUPONS..
21:31 06/29/82
TEST 19520 RUN 4
Y-AXIS CH 49
YMAX = .2475E 05
YMIN = .4882E 02
X-AXIS CH 53
XMAX = .2453E 05
XMIN = -.6834E 02
X1000
25.0
20.0
15.0
10.0
5.00
0.
STRESS
17-3, STRESS VS. LONGITUDINAL STRAIN
-5.00
0.
5.00
10.0
15.0
20.0
25.0
LONG.STRAIN
X1000

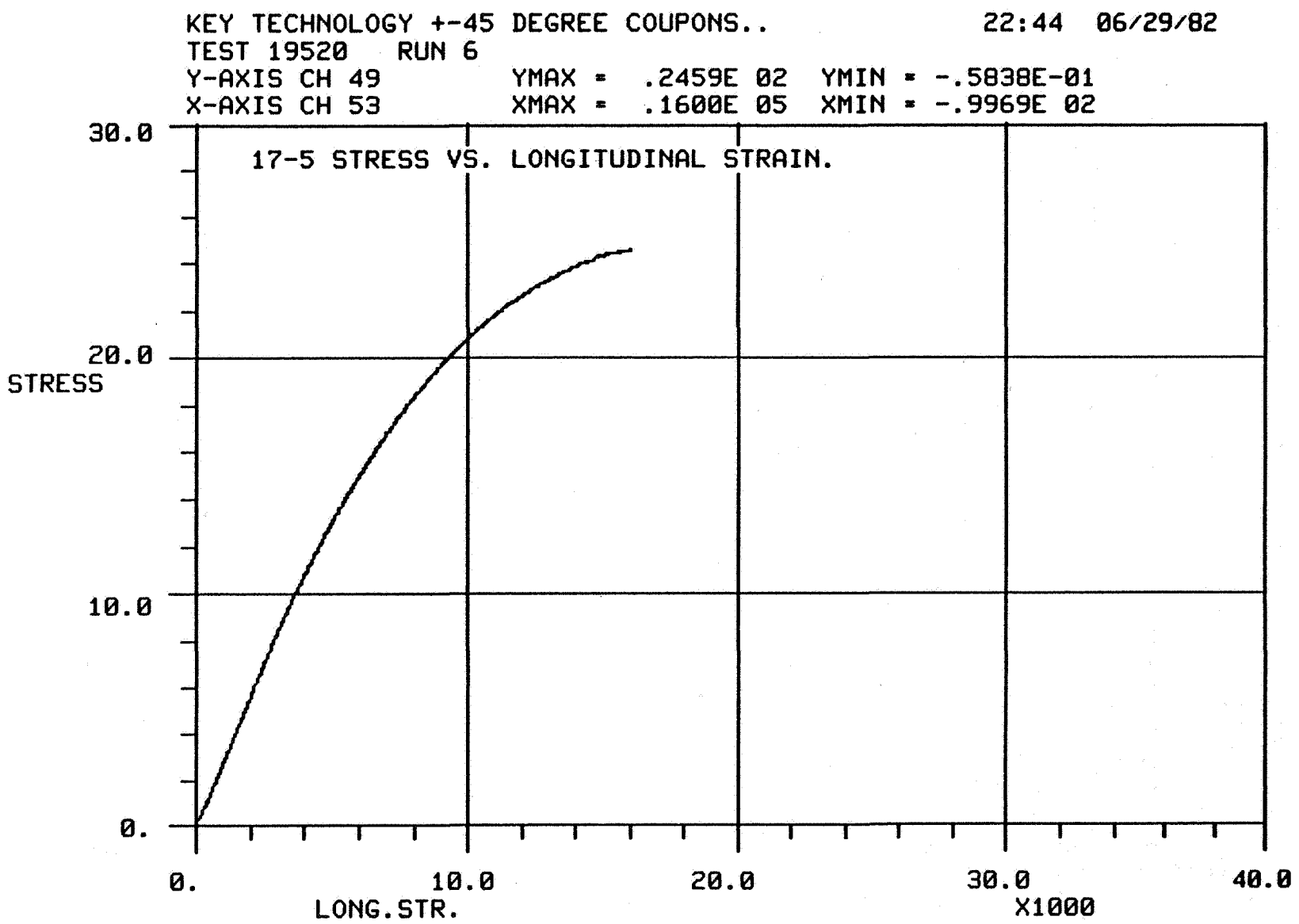

KEY TECHNOLOGY +-45 DEGREE COUPONS..
21:31 06/29/82
TEST 19520 RUN 4
Y-AXIS CH 49
YMAX = .2474E 02
YMIN = .4882E-01
X-AXIS CH 51
XMAX = .7557E 02
XMIN = -.1734E 05
17-3 STRESS VS. TRANSVERSE STRAIN.
30.0
20.0
10.0
0.
STRESS
-40.0
-30.0
-20.0
-10.0
0.
TRANS.STR.
X1000

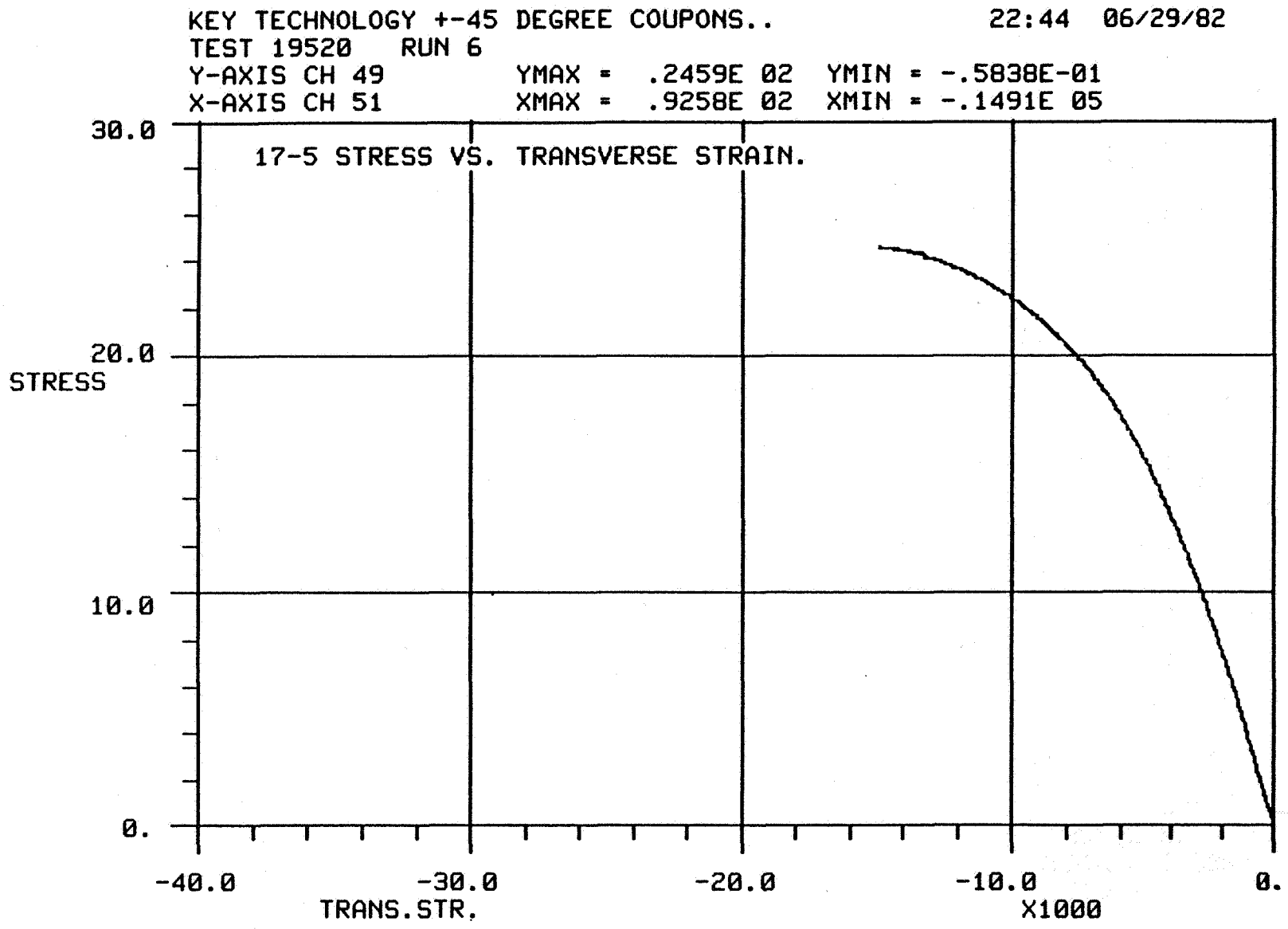

KEY TECHNOLOGY +-45 DEGREE COUPONS..
TEST 19520 RUN 4 FMAX = .0 TRUNC PCT. = 90.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0625 WIDTH = 1.0018
SHEAR STRESS,MAX = .1234E 05 SHEAR STRAIN,MAX = .4545E 05
X1000
12.5
10.0
7.50
SHEAR
STRESS-PSI
5.00
2.50
0.
-2.50
17-3
-10.0
0.
10.0
20.0
30.0
40.0
50.0
MICROSTRAIN
X1000

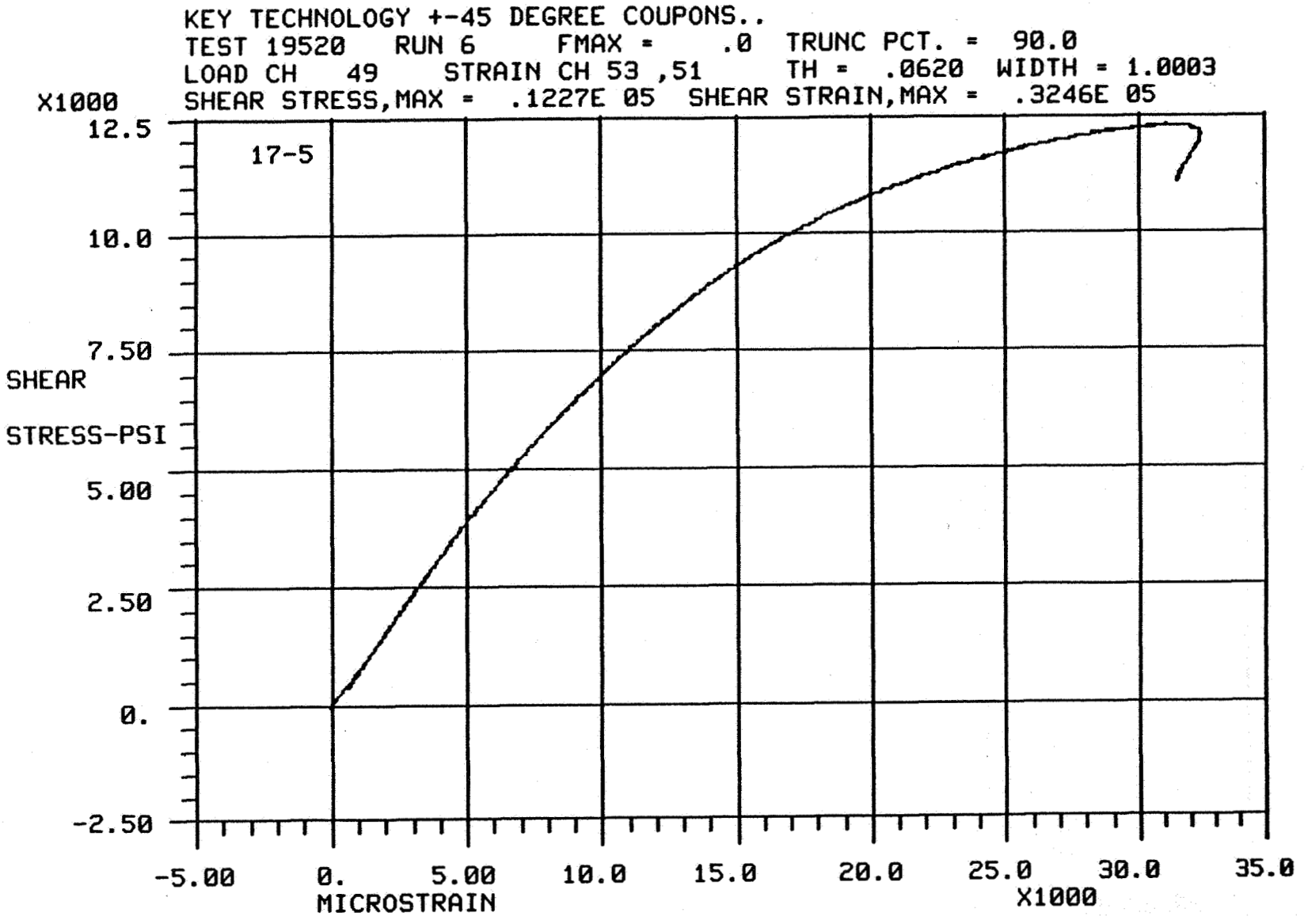

KEY TECHNOLOGY +-45 DEGREE COUPONS..
22:05 06/29/82
TEST 19520 RUN 5
Y-AXIS CH 49
YMAX = .2472E 05
YMIN = -.1948E 02
X-AXIS CH 53
XMAX = .4000E 05
XMIN = -.1943E 02
X1000
17-4, STRESS VS. LONG. STRAIN
25.0
20.0
15.0
STRESS
10.0
5.00
0.
-5.00
-10.0
0.
10.0
20.0
30.0
40.0
LONG.STRAIN
X1000


KEY TECHNOLOGY +-45 DEGREE COUPONS..
22:05 06/29/82
TEST 19520 RUN 5
Y-AXIS CH 49
YMAX = .2472E 02
YMIN = .7382E-01
X-AXIS CH 51
XMAX = .5854E 02
XMIN = -.1693E 05
17-4 STRESS VS. TRANSVERSE STRAIN.
30.0
20.0
10.0
0.
STRESS
-40.0
-30.0
-20.0
-10.0
0.
TRANS.STR.
X1000


KEY TECHNOLOGY +-45 DEGREE COUPONS..
TEST 19520 RUN 5 FMAX = .0 TRUNC PCT. = 90.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0621 WIDTH = 1.0015
SHEAR STRESS,MAX = .1230E 05 SHEAR STRAIN,MAX = .8007E 05
X1000
12.5
10.0
7.50
SHEAR
STRESS-PSI
5.00
2.50
0.
-2.50
17-4
0.
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
MICROSTRAIN
X1000


KEY TECHNOLOGY +-45 DEGREE COUPONS..
22:44 06/29/82
TEST 19520 RUN 6
Y-AXIS CH 49
YMAX = .2459E 02
YMIN = -.5838E-01
X-AXIS CH 53
XMAX = .1600E 05
XMIN = -.9969E 02
17-5 STRESS VS. LONGITUDINAL STRAIN.
30.0
20.0
10.0
0.
STRESS
0.
10.0
20.0
30.0
40.0
LONG.STR.
X1000


KEY TECHNOLOGY +-45 DEGREE COUPONS..
22:44 06/29/82
TEST 19520 RUN 6
Y-AXIS CH 49
YMAX = .2459E 02
YMIN = -.5838E-01
X-AXIS CH 51
XMAX = .9258E 02
XMIN = -.1491E 05
17-5 STRESS VS. TRANSVERSE STRAIN.
30.0
20.0
10.0
0.
STRESS
-40.0
-30.0
-20.0
-10.0
0.
TRANS.STR.
X1000


KEY TECHNOLOGY +-45 DEGREE COUPONS..
TEST 19520 RUN 6 FMAX = .0 TRUNC PCT. = 90.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0620 WIDTH = 1.0003
SHEAR STRESS,MAX = .1227E 05 SHEAR STRAIN,MAX = .3246E 05
X1000
12.5
10.0
7.50
SHEAR
STRESS-PSI
5.00
2.50
0.
-2.50
17-5
-5.00
0.
5.00
10.0
15.0
20.0
25.0
30.0
35.0
MICROSTRAIN
X1000

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454/2220

TO	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11546-45
FROM		SUBJECT	REF
MODEL			WO EWA

CONTINUED FROM E.N. #

SECTION	I.D. 37-1	37-2	37-3	37-4	37-5
1	0.0646	0.0660	0.0641	0.0643	0.0651
2	0.0653	0.0641	0.0642	0.0650	0.0653
3	0.0645	0.0649	0.0651	0.0658	0.0653
4	0.0652	0.0651	0.0657	0.0654	0.0653
5	0.0656	0.0643	0.0640	0.0643	0.0657
6	0.0647	0.0655	0.0649	0.0652	0.0651
AVE	0.0650	0.0650	0.0646	0.0650	0.0654
7	1.0018	1.0011	1.0007	1.0015	1.0011
8	1.0018	1.0012	1.0009	1.0011	1.0010
9	1.0016	1.0011	1.0011	1.0010	1.0011
AVE	1.0017	1.0011	1.0009	1.0012	1.0011
AREA	0.0651	0.0651	0.0647	0.0651	0.0655
TEST NO.	19350	19350	19350	19350	19350
LOAD #	1 120.3	1 120.5	1 120.4	1 120.4	1 120.5
CIMX SCAN				1 120.5	1 120.3

69:3:51 ϵ_T 300#/foot 400#/foot

70:4:53 ϵ_L 200#/foot 400#/foot

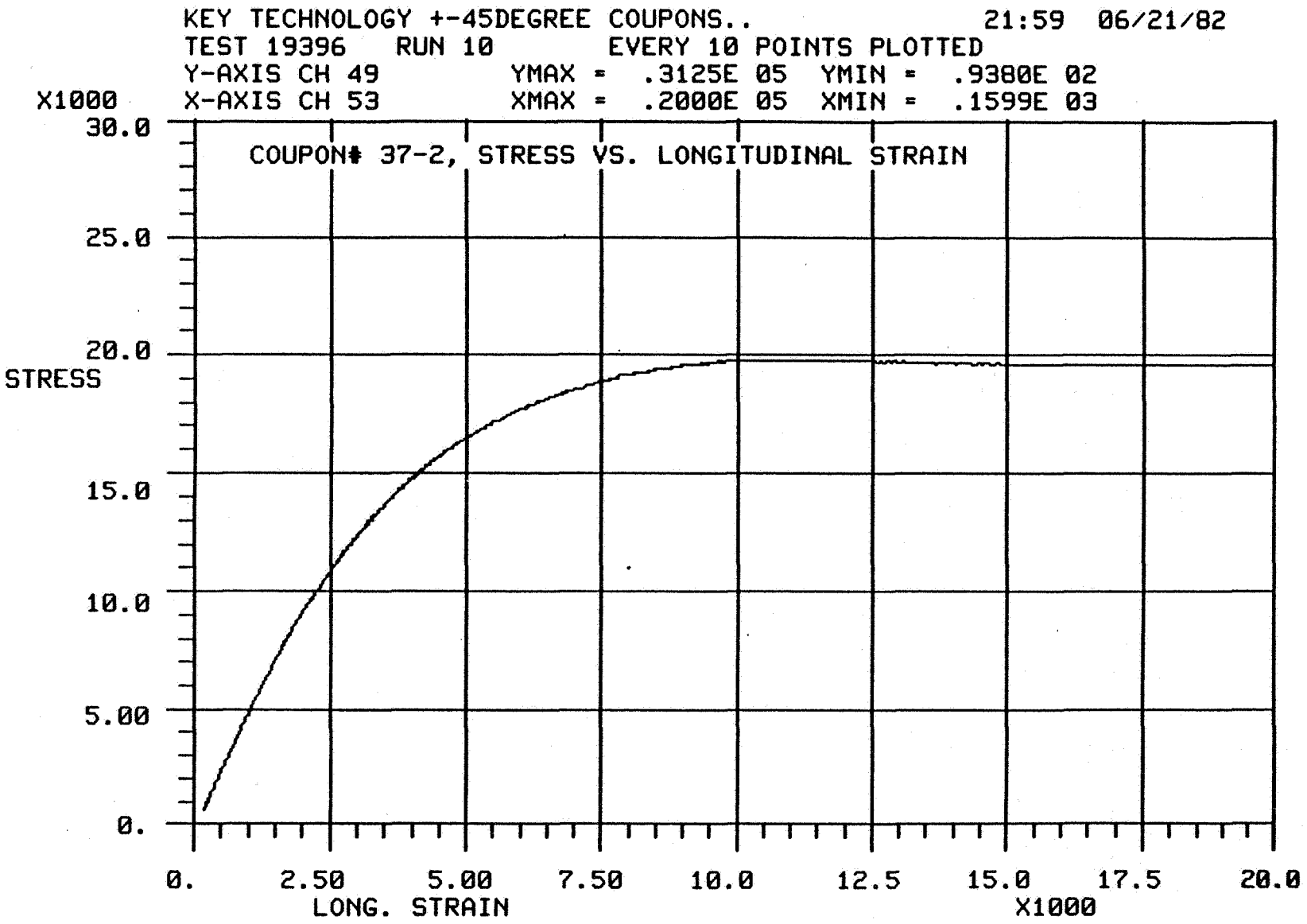
:49 LOAD 500/foot

$$\epsilon_T = \frac{120.3 \times 10^6}{2.125(5012 \times 0.3)} = 1130\mu\epsilon$$

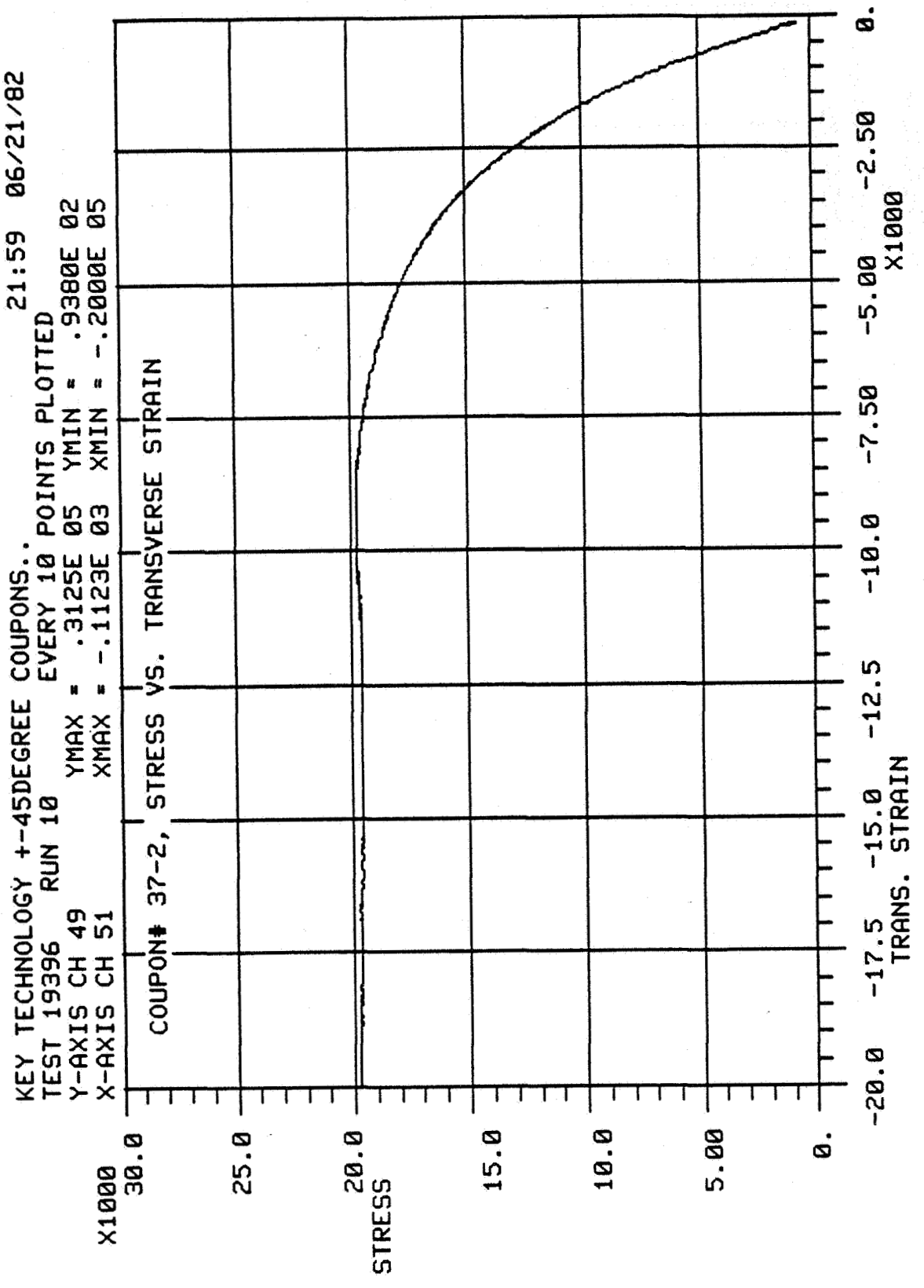
$$\epsilon_L = \frac{120.4 \times 10^6}{3.095(5012 \times 0.4)} = 1147\mu\epsilon$$

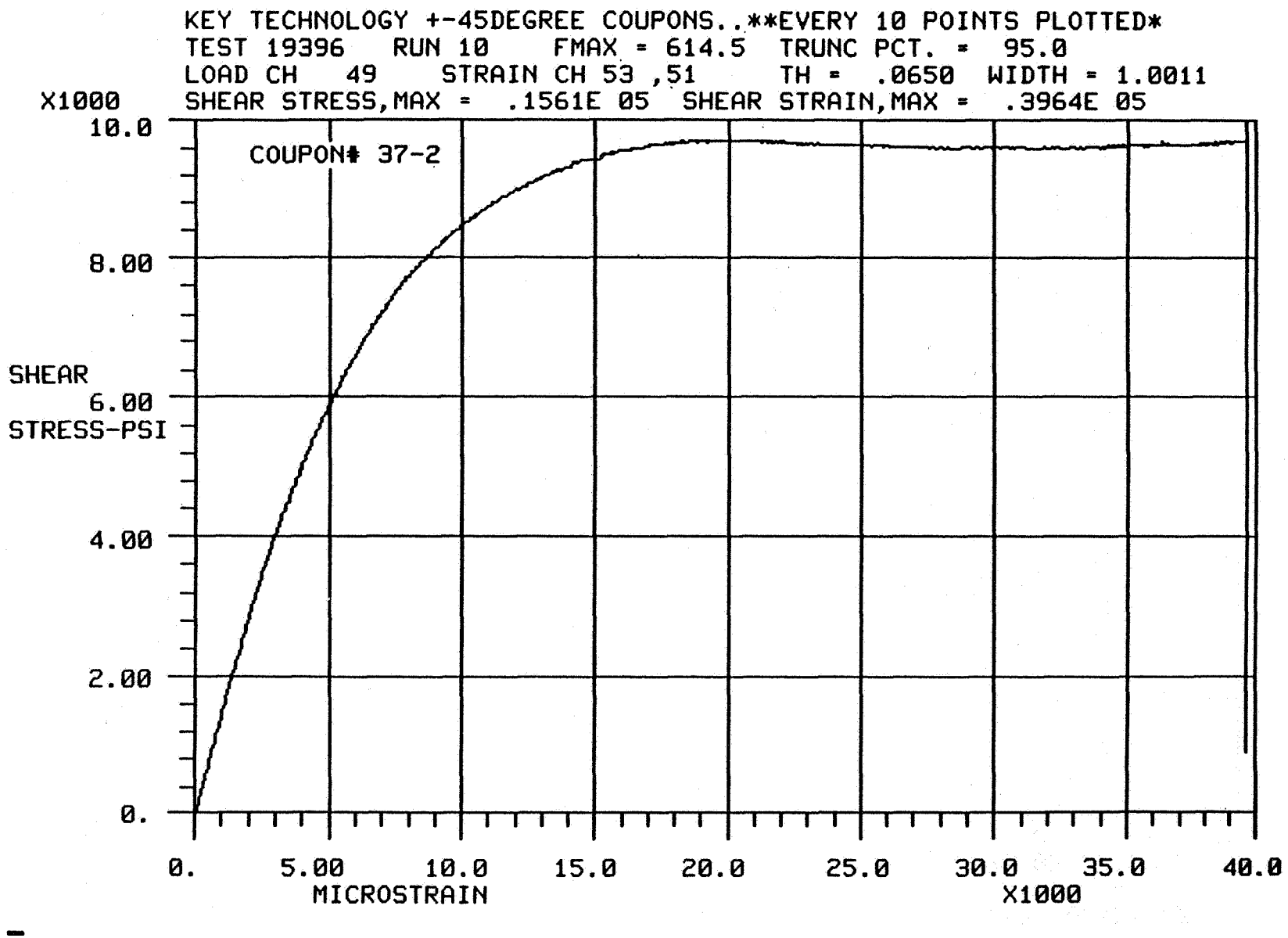
FILE 0045 DEGREE

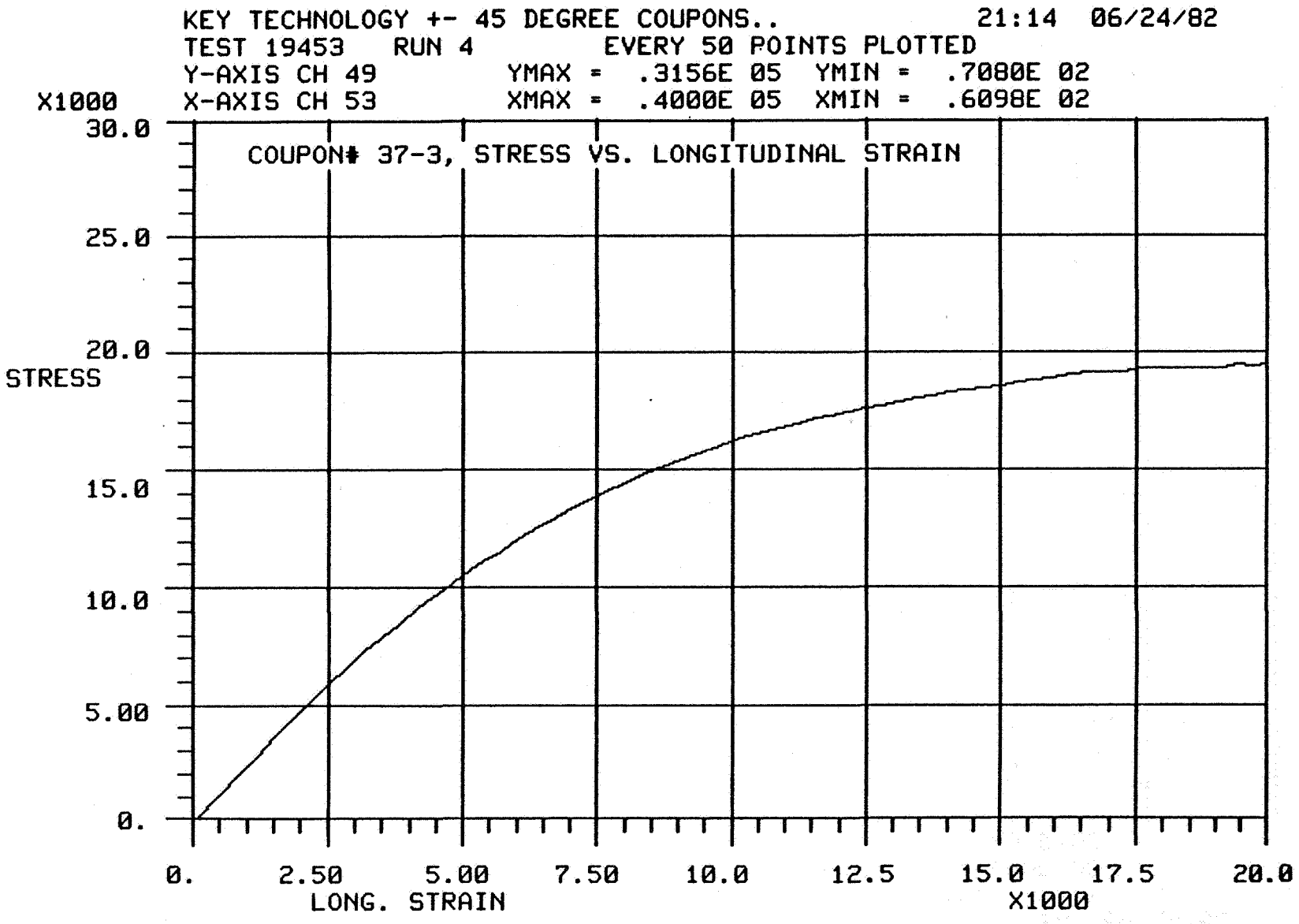
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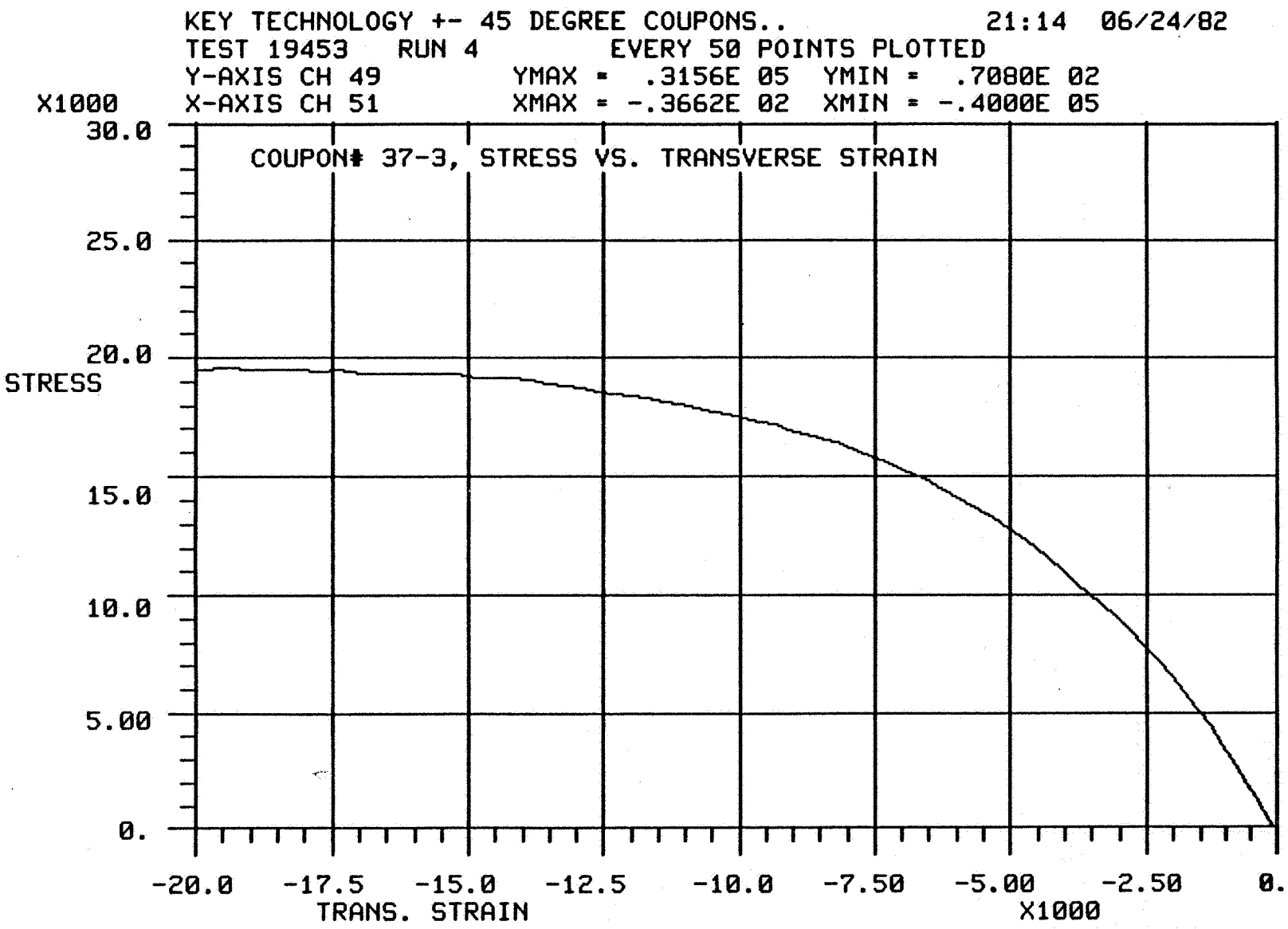

KEY TECHNOLOGY +-45DEGREE COUPONS..
21:59 06/21/82
TEST 19396 RUN 10
EVERY 10 POINTS PLOTTED
Y-AXIS CH 49
YMAX = .3125E 05 YMIN = .9380E 02
X-AXIS CH 53
XMAX = .2000E 05 XMIN = .1599E 03
X1000
30.0
25.0
20.0
STRESS
15.0
10.0
5.00
0.
COUPON# 37-2, STRESS VS. LONGITUDINAL STRAIN
0.
2.50
5.00
7.50
10.0
12.5
15.0
17.5
20.0
LONG. STRAIN
X1000

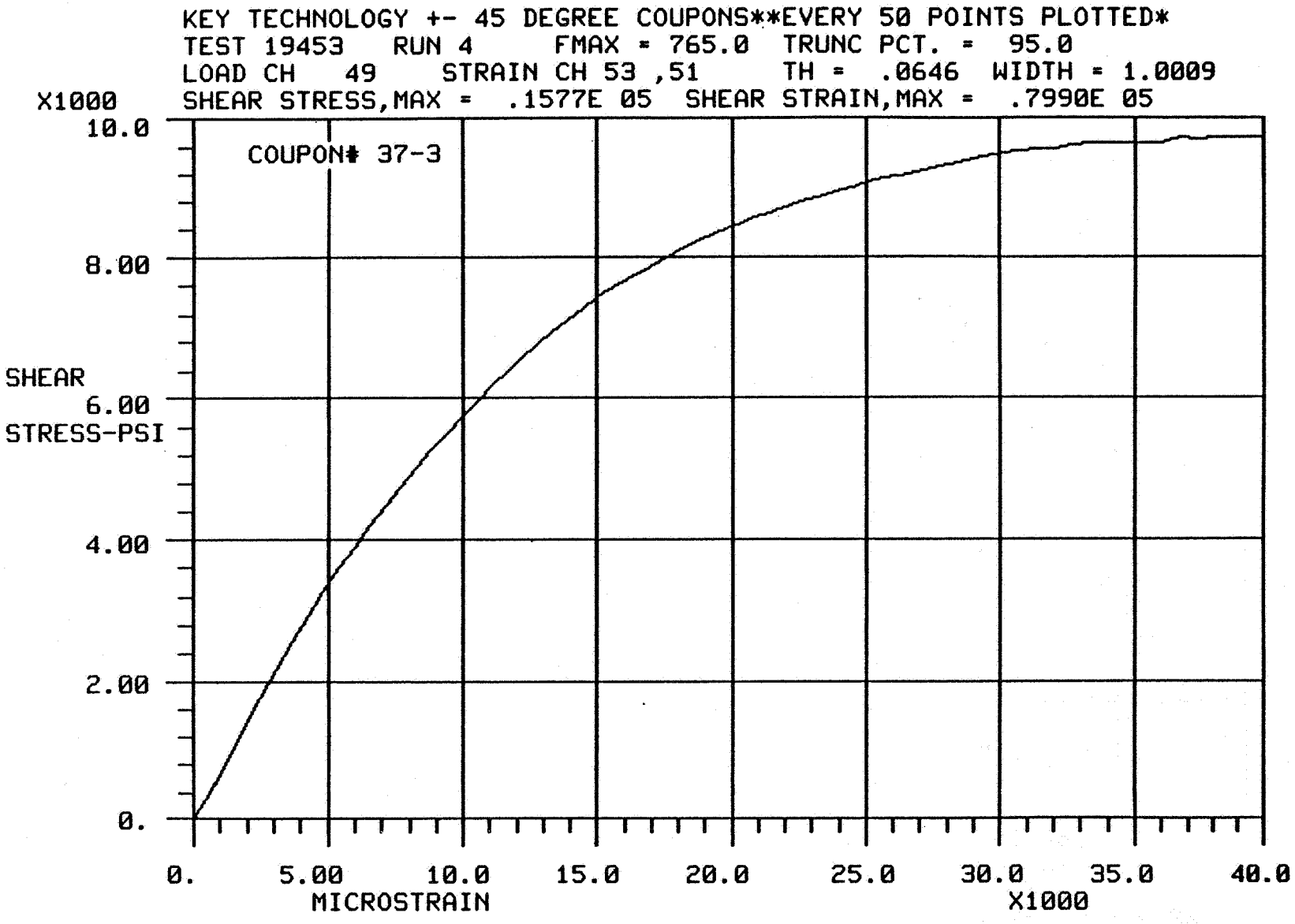
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OF POOR QUALITY

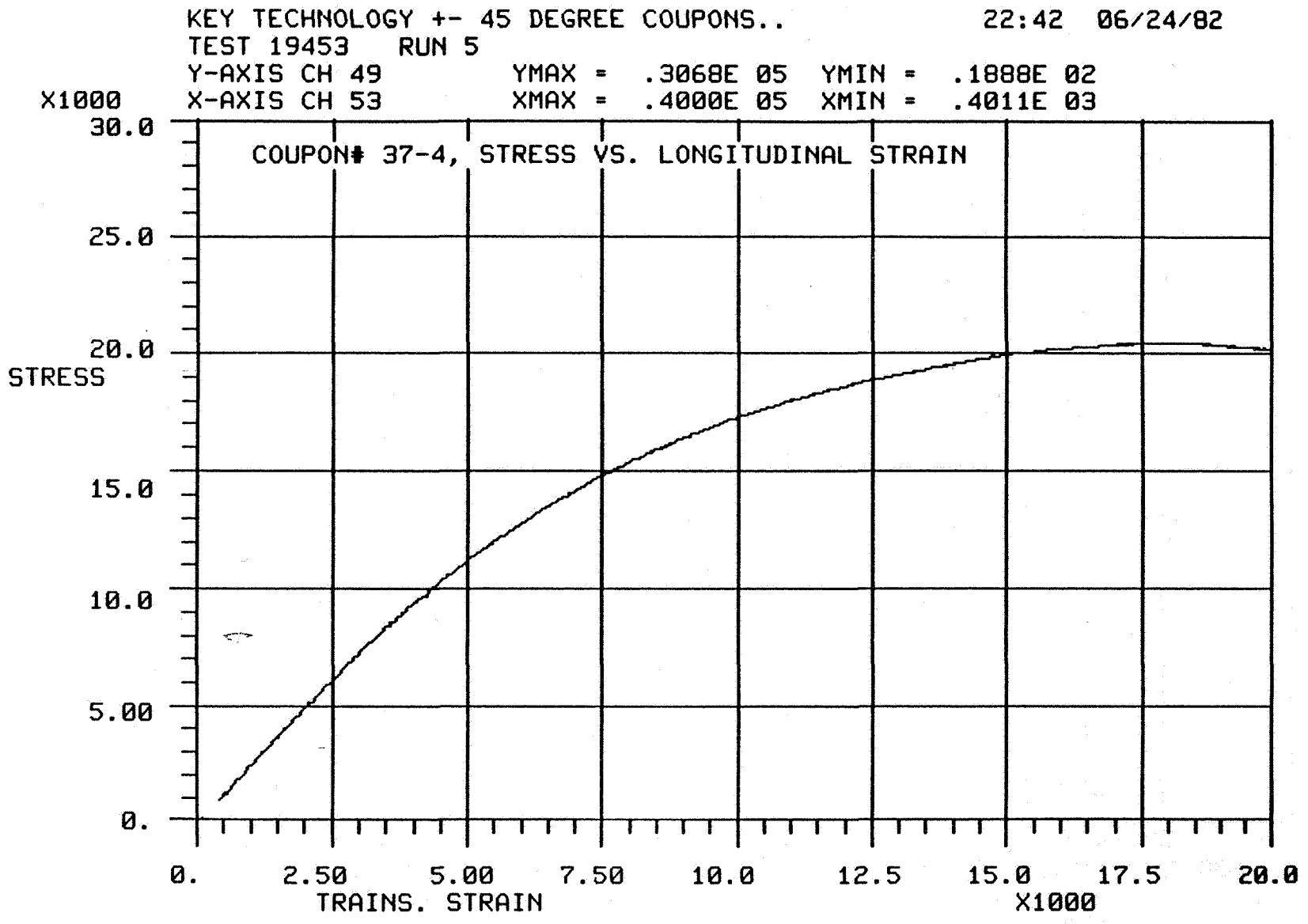


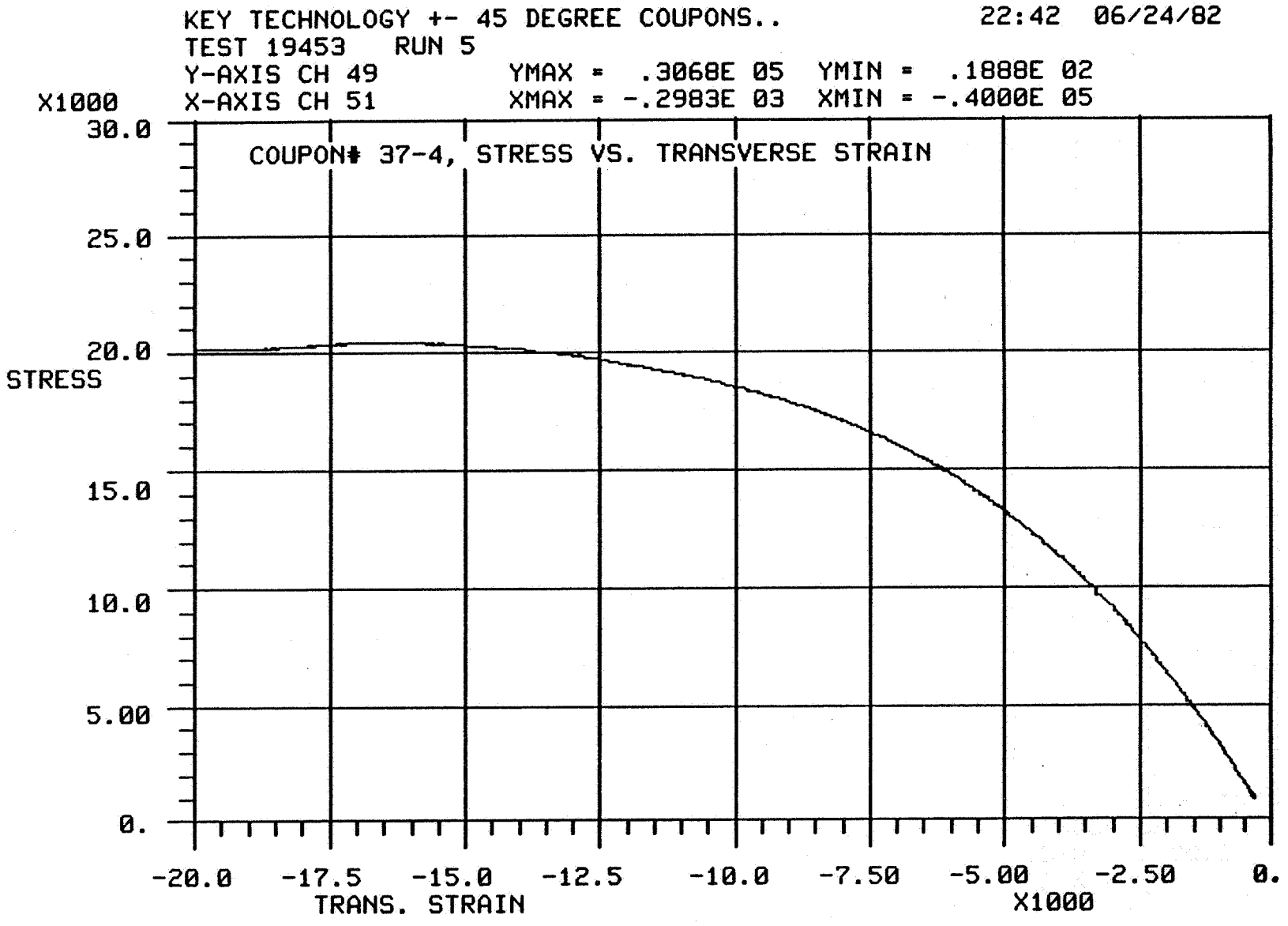

KEY TECHNOLOGY +-45DEGREE COUPONS..**EVERY 10 POINTS PLOTTED*
TEST 19396 RUN 10 FMAX = 614.5 TRUNC PCT. = 95.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0650 WIDTH = 1.0011
SHEAR STRESS,MAX = .1561E 05 SHEAR STRAIN,MAX = .3964E 05
X1000
10.0
8.00
6.00
4.00
2.00
0.
SHEAR
STRESS-PSI
COUPON# 37-2
0.
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
MICROSTRAIN
X1000

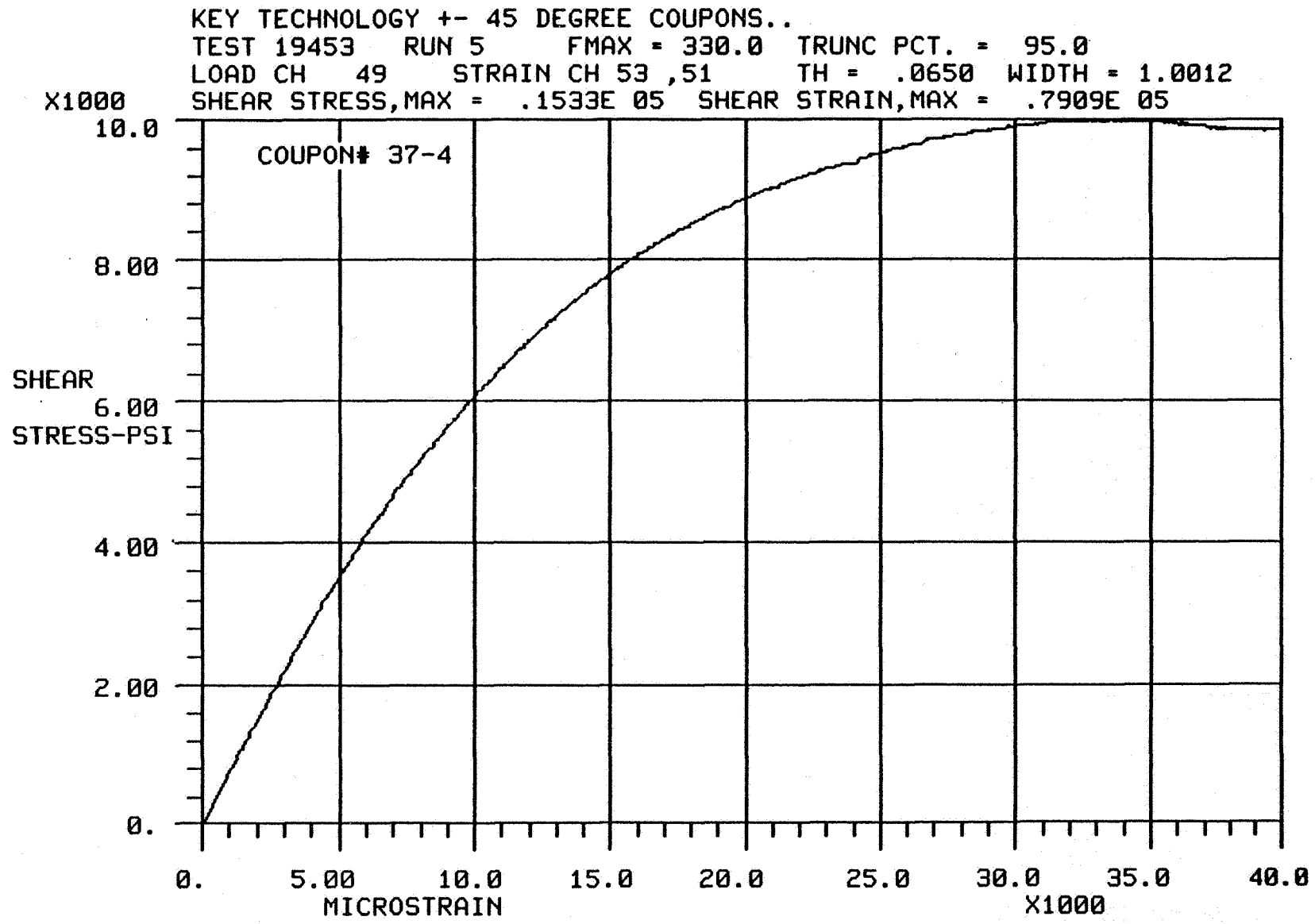

KEY TECHNOLOGY +- 45 DEGREE COUPONS..
21:14 06/24/82
TEST 19453 RUN 4
EVERY 50 POINTS PLOTTED
Y-AXIS CH 49
YMAX = .3156E 05
YMIN = .7080E 02
X-AXIS CH 53
XMAX = .4000E 05
XMIN = .6098E 02
X1000
COUPON# 37-3, STRESS VS. LONGITUDINAL STRAIN
30.0
25.0
20.0
STRESS
15.0
10.0
5.00
0.
0.
2.50
5.00
7.50
10.0
12.5
15.0
17.5
20.0
LONG. STRAIN
X1000

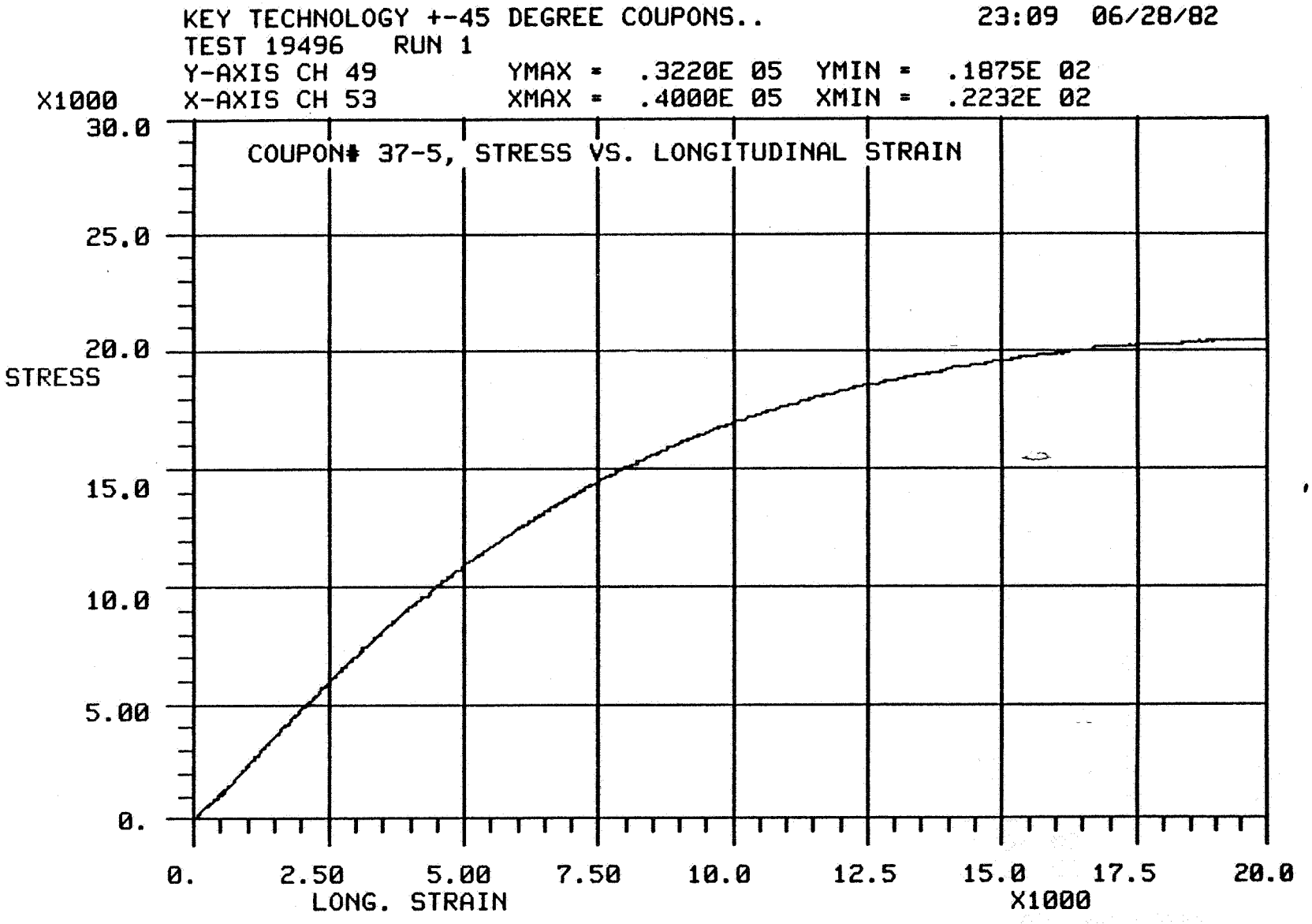

KEY TECHNOLOGY +- 45 DEGREE COUPONS..
21:14 06/24/82
TEST 19453 RUN 4
EVERY 50 POINTS PLOTTED
Y-AXIS CH 49
YMAX = .3156E 05 YMIN = .7080E 02
X-AXIS CH 51
XMAX = -.3662E 02 XMIN = -.4000E 05
X1000
30.0
25.0
20.0
STRESS
15.0
10.0
5.00
0.
COUPON# 37-3, STRESS VS. TRANSVERSE STRAIN
-20.0
-17.5
-15.0
-12.5
-10.0
-7.50
-5.00
-2.50
0.
TRANS. STRAIN
X1000

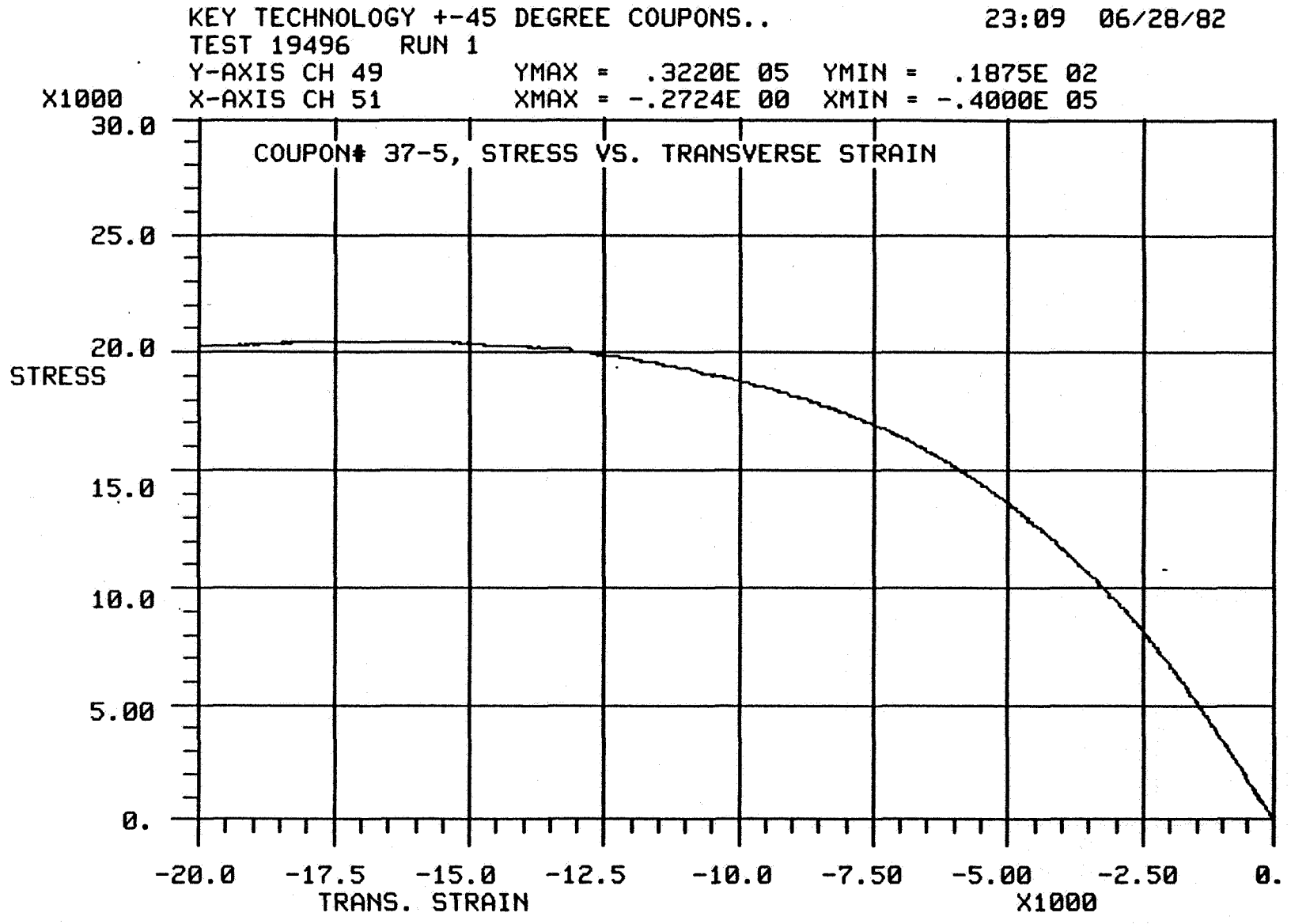

KEY TECHNOLOGY +- 45 DEGREE COUPONS**EVERY 50 POINTS PLOTTED*
TEST 19453 RUN 4 FMAX = 765.0 TRUNC PCT. = 95.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0646 WIDTH = 1.0009
SHEAR STRESS,MAX = .1577E 05 SHEAR STRAIN,MAX = .7990E 05
X1000
10.0
COUPON# 37-3
8.00
SHEAR
6.00
STRESS-PSI
4.00
2.00
0.
0.
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
MICROSTRAIN
X1000

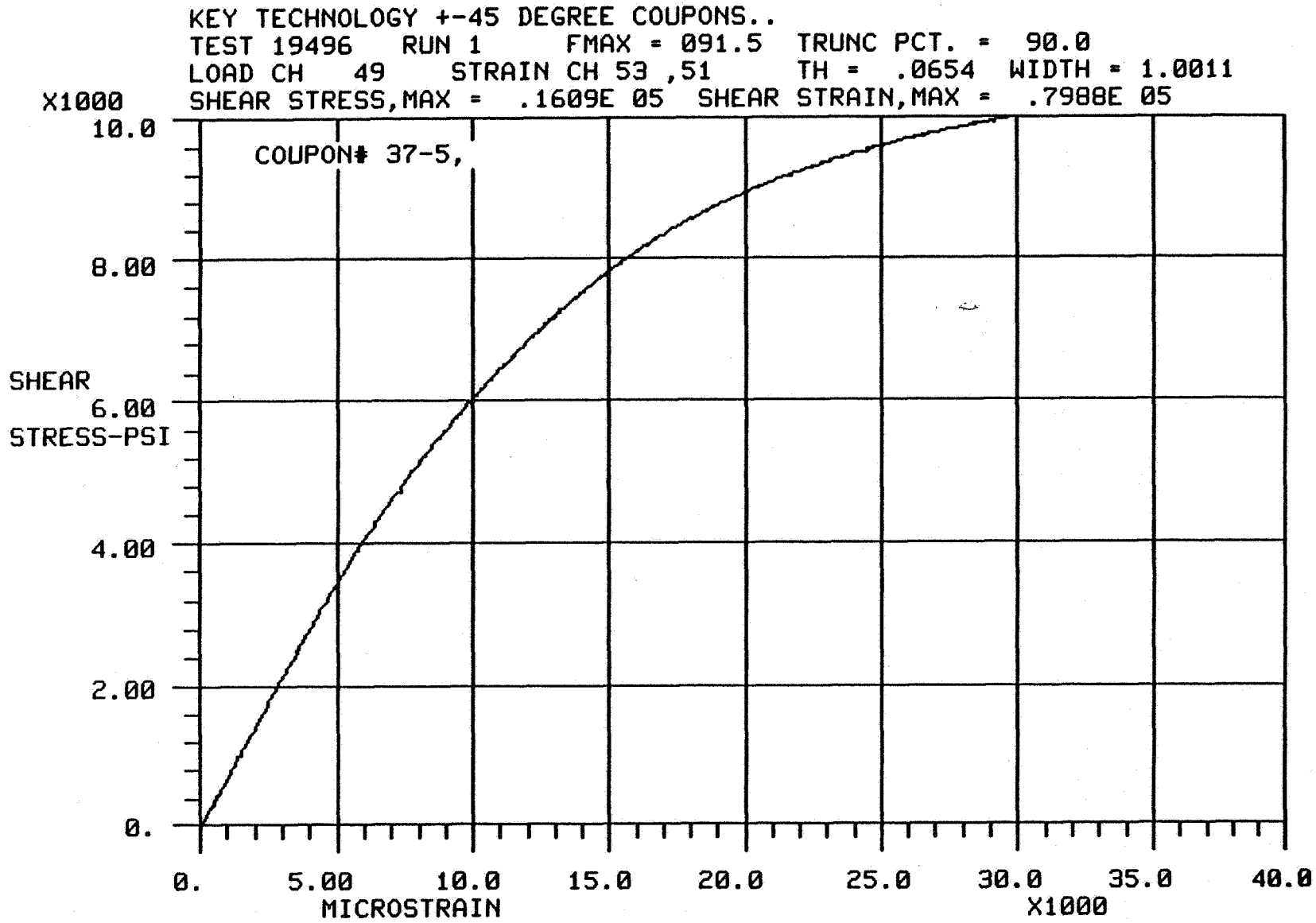

KEY TECHNOLOGY +- 45 DEGREE COUPONS..
22:42 06/24/82
TEST 19453 RUN 5
Y-AXIS CH 49
YMAX = .3068E 05
YMIN = .1888E 02
X1000
X-AXIS CH 53
XMAX = .4000E 05
XMIN = .4011E 03
COUPON# 37-4, STRESS VS. LONGITUDINAL STRAIN
30.0
25.0
20.0
STRESS
15.0
10.0
5.00
0.
0.
2.50
5.00
7.50
10.0
12.5
15.0
17.5
20.0
TRAINS. STRAIN
X1000


KEY TECHNOLOGY +- 45 DEGREE COUPONS..
22:42 06/24/82
TEST 19453 RUN 5
Y-AXIS CH 49
YMAX = .3068E 05
YMIN = .1888E 02
X-AXIS CH 51
XMAX = -.2983E 03
XMIN = -.4000E 05
X1000
COUPON# 37-4, STRESS VS. TRANSVERSE STRAIN
30.0
25.0
20.0
STRESS
15.0
10.0
5.00
0.
-20.0
-17.5
-15.0
-12.5
-10.0
-7.50
-5.00
-2.50
0.
TRANS. STRAIN
X1000


KEY TECHNOLOGY +- 45 DEGREE COUPONS..
TEST 19453 RUN 5 FMAX = 330.0 TRUNC PCT. = 95.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0650 WIDTH = 1.0012
SHEAR STRESS,MAX = .1533E 05 SHEAR STRAIN,MAX = .7909E 05
X1000
10.0
8.00
6.00
4.00
2.00
0.
SHEAR
STRESS-PSI
COUPON# 37-4
0.
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
MICROSTRAIN
X1000


KEY TECHNOLOGY +-45 DEGREE COUPONS..
23:09 06/28/82
TEST 19496 RUN 1
Y-AXIS CH 49
YMAX = .3220E 05
YMIN = .1875E 02
X-AXIS CH 53
XMAX = .4000E 05
XMIN = .2232E 02
X1000
COUPON# 37-5, STRESS VS. LONGITUDINAL STRAIN
30.0
25.0
20.0
STRESS
15.0
10.0
5.00
0.
0.
2.50
5.00
7.50
10.0
12.5
15.0
17.5
20.0
LONG. STRAIN
X1000


KEY TECHNOLOGY +-45 DEGREE COUPONS..
23:09 06/28/82
TEST 19496 RUN 1
Y-AXIS CH 49
YMAX = .3220E 05
YMIN = .1875E 02
X-AXIS CH 51
XMAX = -.2724E 00
XMIN = -.4000E 05
X1000
COUPON# 37-5, STRESS VS. TRANSVERSE STRAIN
30.0
25.0
20.0
STRESS
15.0
10.0
5.00
0.
-20.0
-17.5
-15.0
-12.5
-10.0
-7.50
-5.00
-2.50
0.
TRANS. STRAIN
X1000


KEY TECHNOLOGY +-45 DEGREE COUPONS..
TEST 19496 RUN 1 FMAX = 091.5 TRUNC PCT. = 90.0
LOAD CH 49 STRAIN CH 53 ,51 TH = .0654 WIDTH = 1.0011
SHEAR STRESS,MAX = .1609E 05 SHEAR STRAIN,MAX = .7988E 05
X1000
10.0
8.00
6.00
4.00
2.00
0.
SHEAR
STRESS-PSI
COUPON# 37-5,
0.
5.00
10.0
15.0
20.0
25.0
30.0
35.0
40.0
MICROSTRAIN
X1000

APPENDIX B5

ORIGINAL PAGE IS
OF POOR QUALITY

TO	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11223-21
FROM		SUBJECT 0° TENSION GEOMETRY	REF
MODEL			W.O. EWA

CONTINUED FROM E.N. #

PANEL 21 AS4/3502

LOCATION	I.D. 21-1T	21-2T	21-3T	21-4T	21-5T	21-6T
1	0.0567	0.0571	0.0589	0.0597	0.0607	0.0534
2	0.0568	0.0564	0.0589	0.0602	0.0593	0.0588
3	0.0572	0.0572	0.0597	0.0599	0.0593	0.0586
4	0.0559	0.0596	0.0607	0.0585	0.0590	0.0592
5	0.0547	0.0595	0.0607	0.0582	0.0584	0.0584
6	0.0542	0.0584	0.0603	0.0586	0.0587	0.0599
AVE	0.0559	0.0577	0.0600	0.0592	0.0591	0.0587
7	0.9915	1.0051	1.0075	1.0069	1.0088	1.0045
8	0.9912	1.0052	1.0077	1.0067	1.0084	1.0042
9	0.9910	1.0057	1.0097	1.0061	1.0091	1.0049
AVE	0.9912	1.0053	1.0083	1.0066	1.0088	1.0045
AREA	0.0554	0.0580	0.0605	0.0596	0.0596	0.0570
LONG GAGE	1 121.1	1 121.1	1 121.6	1 121.1	121.3 1	1 121.1
TEST/RUN	19273/3	19273/4	19273/2	19274/1	19274/5	19274/10

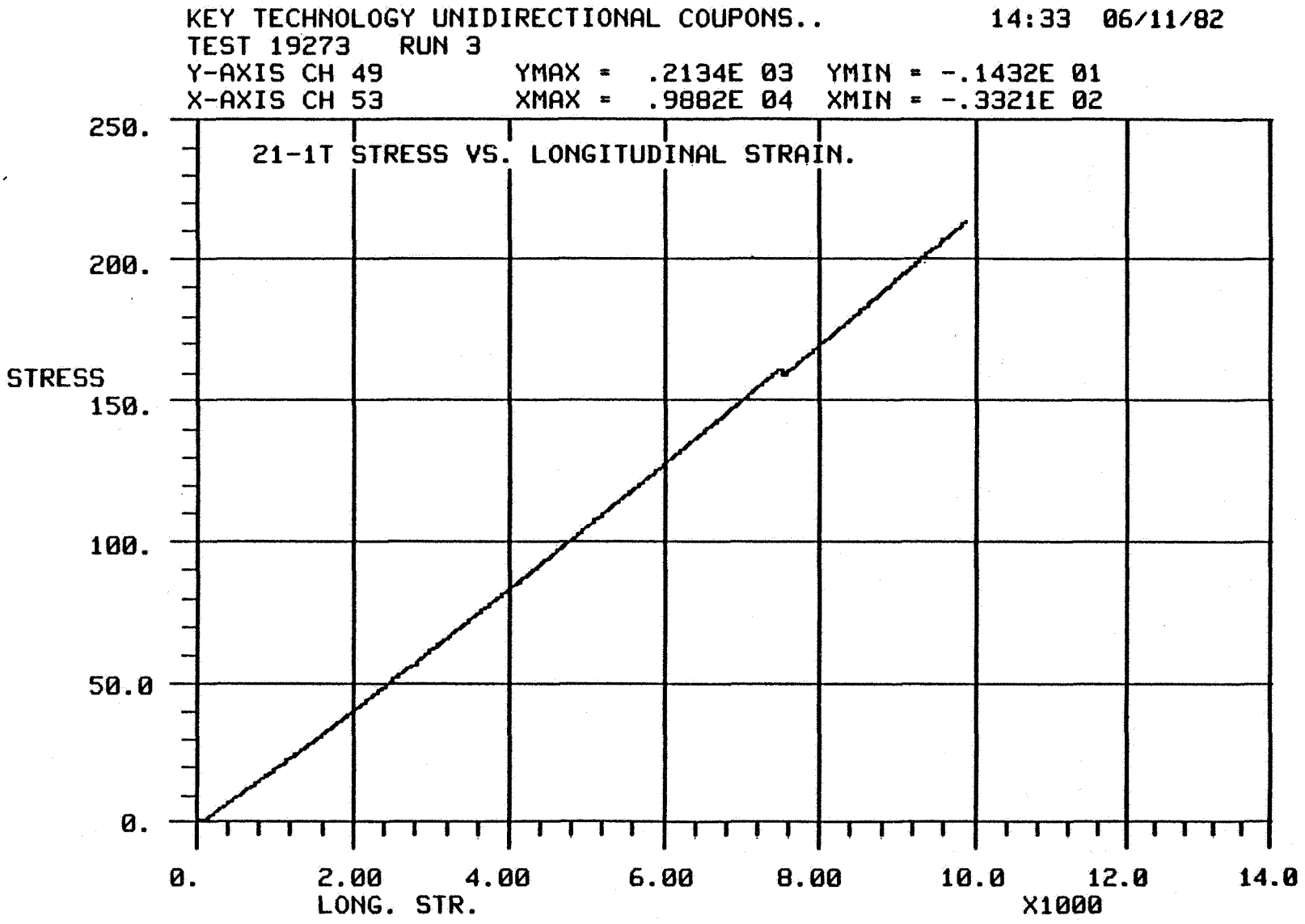
#3: 69:35' = 1153 TRANSVERSE

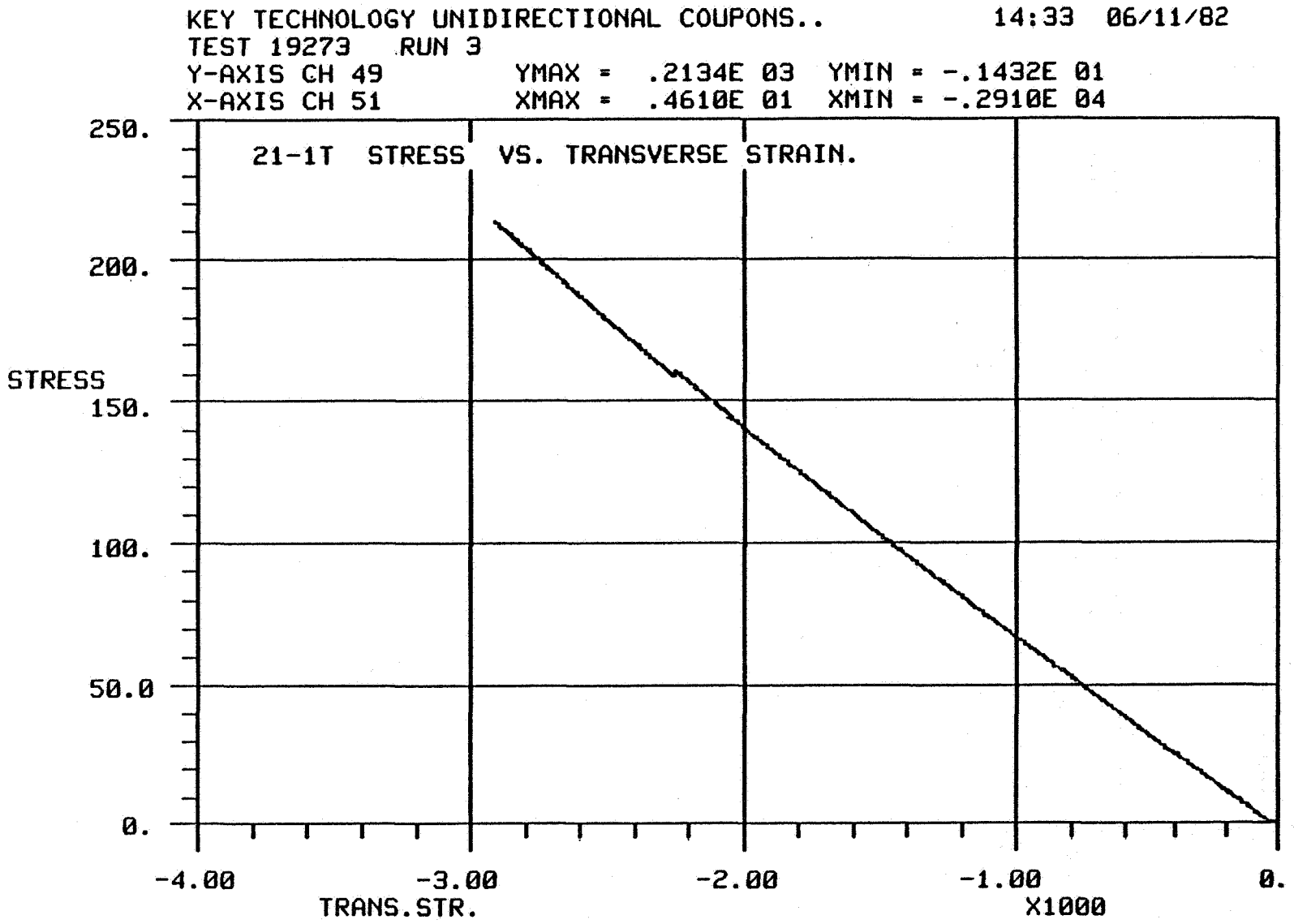
#1: 70:4:53 = 1164 LONGITUDINAL

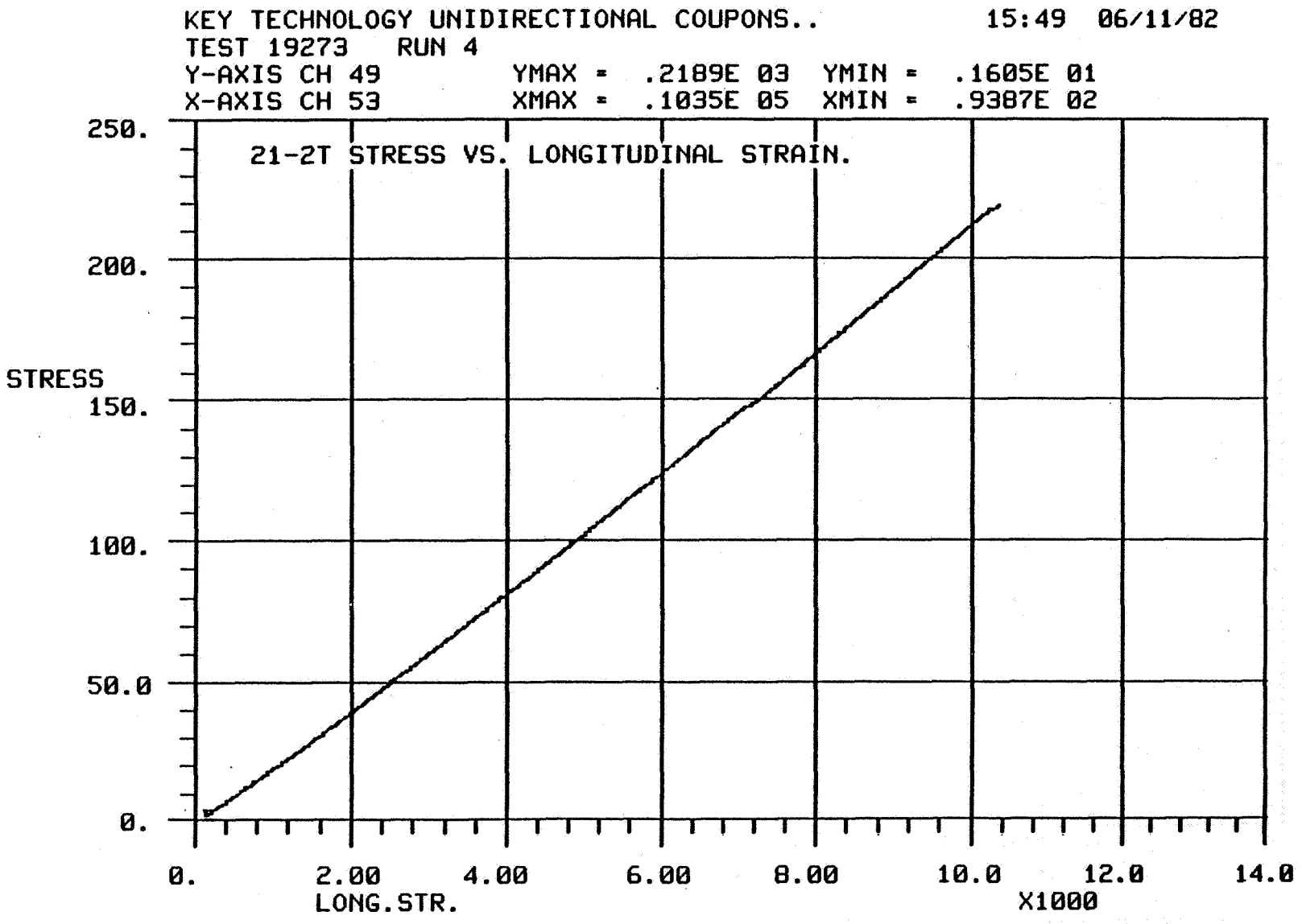
$$\mu\varepsilon_1 = \frac{\delta r \cdot \Omega \times 10^6}{GF \times (Br\Omega + R_{CAL})} = 1164 \qquad \mu\varepsilon_2 = 1153$$

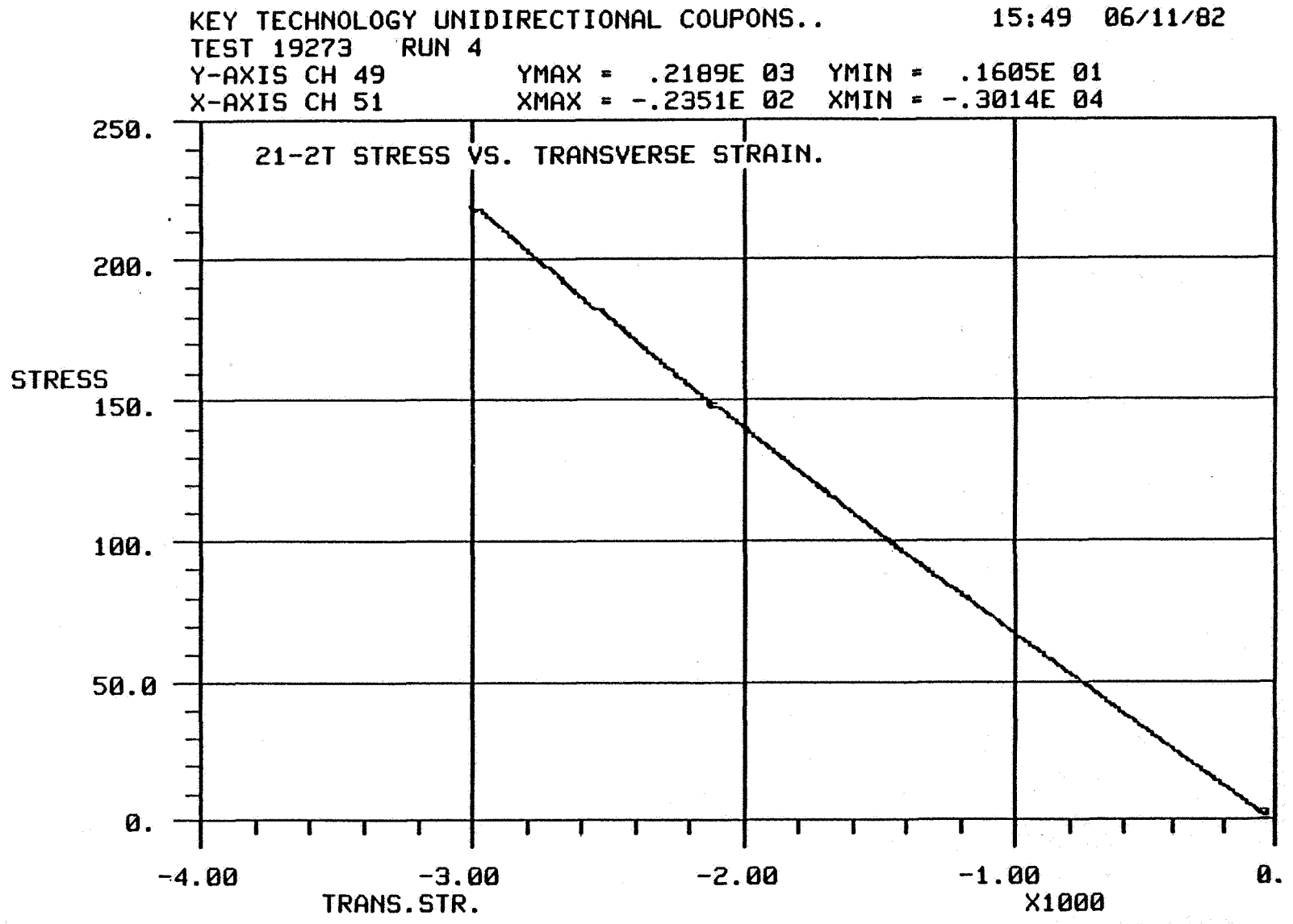
CONTINUED ON E.N. #

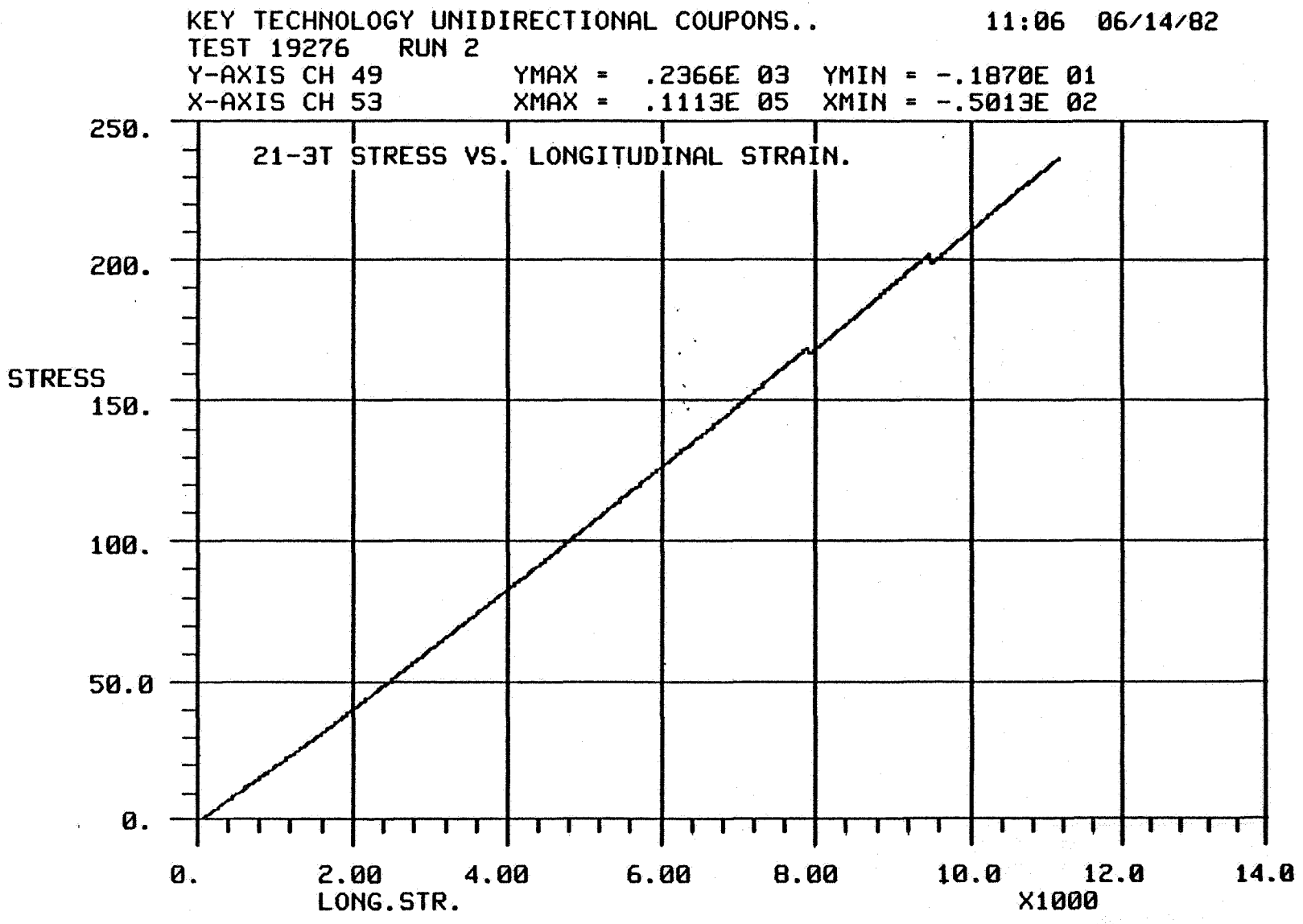
P VS LONG
G VS LONG
G VS TRANS
G VS TIME

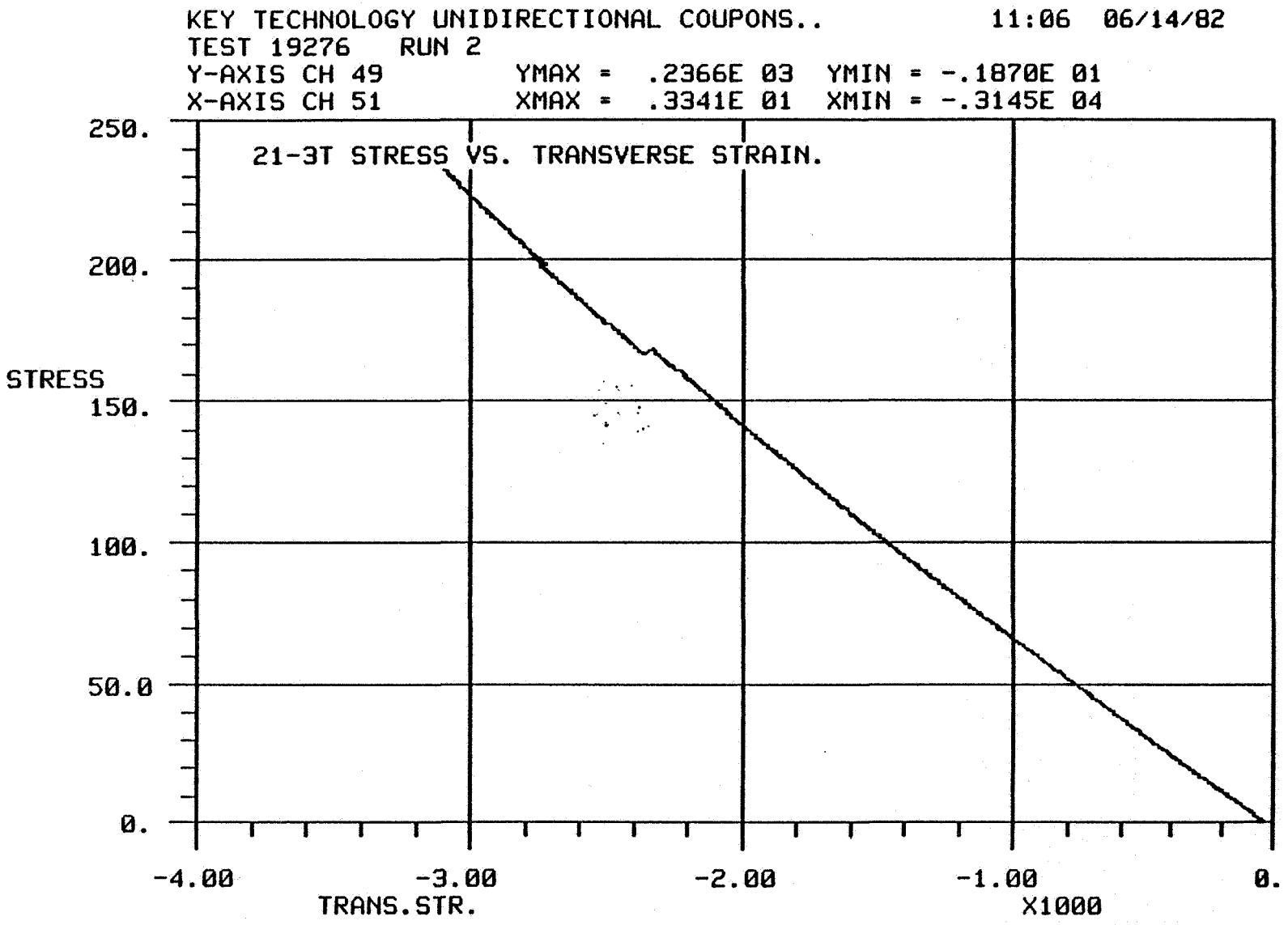

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
14:33 06/11/82
TEST 19273 RUN 3
Y-AXIS CH 49
YMAX = .2134E 03
YMIN = -.1432E 01
X-AXIS CH 53
XMAX = .9882E 04
XMIN = -.3321E 02
21-1T STRESS VS. LONGITUDINAL STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG. STR.
X1000

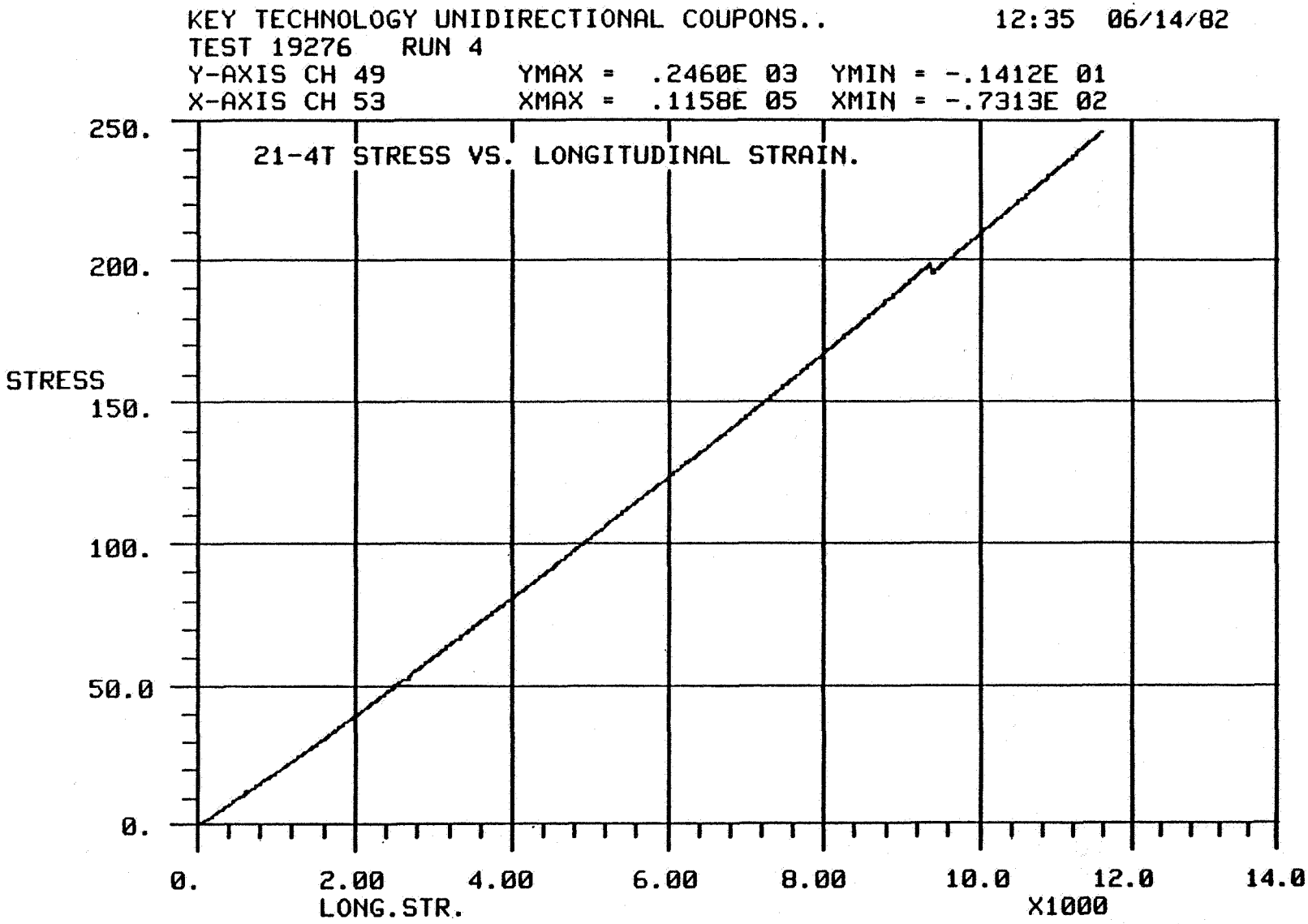

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
14:33 06/11/82
TEST 19273 RUN 3
Y-AXIS CH 49
YMAX = .2134E 03 YMIN = -.1432E 01
X-AXIS CH 51
XMAX = .4610E 01 XMIN = -.2910E 04
21-1T STRESS VS. TRANSVERSE STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

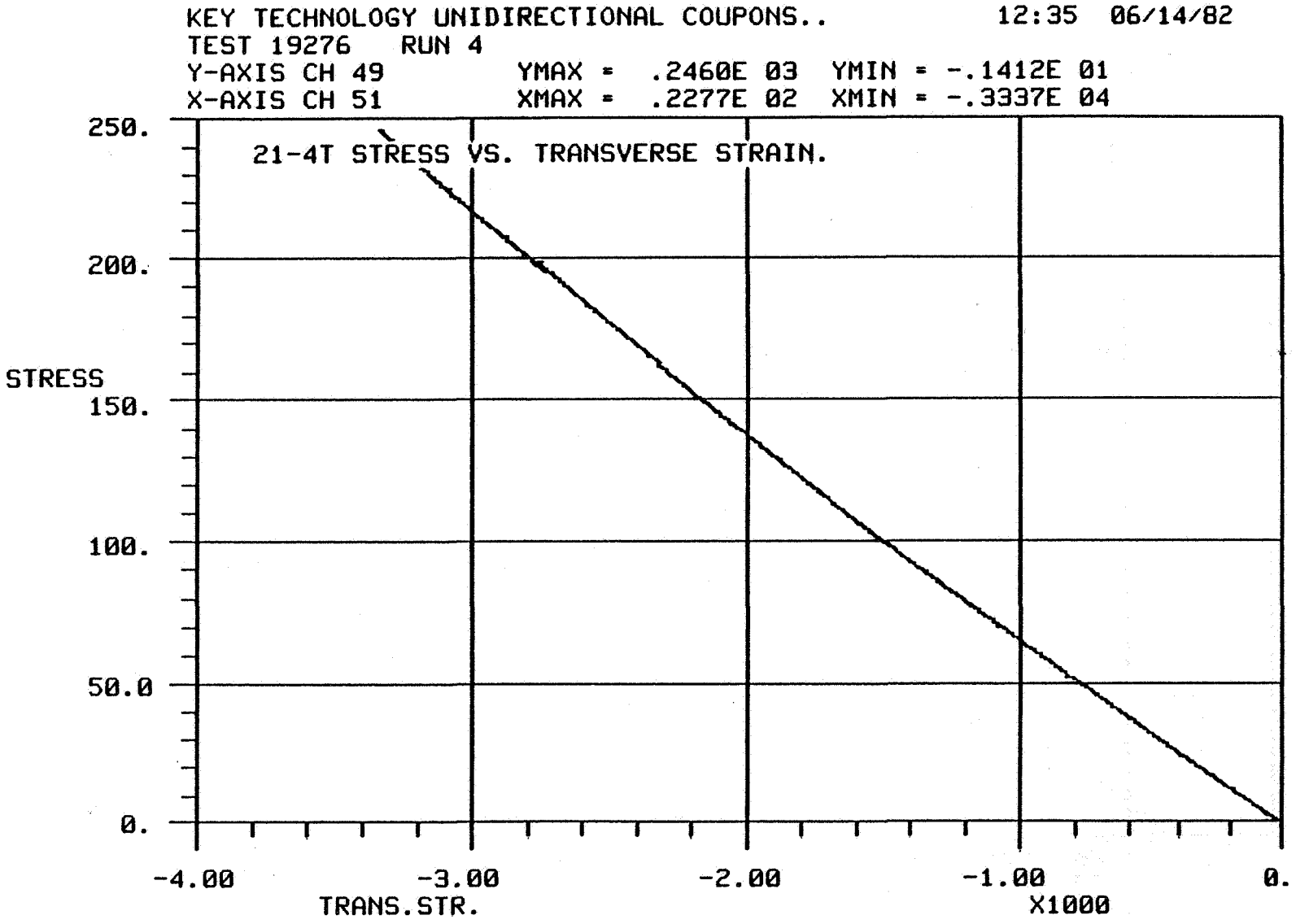

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
15:49 06/11/82
TEST 19273 RUN 4
Y-AXIS CH 49
YMAX = .2189E 03
YMIN = .1605E 01
X-AXIS CH 53
XMAX = .1035E 05
XMIN = .9387E 02
21-2T STRESS VS. LONGITUDINAL STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR.
X1000

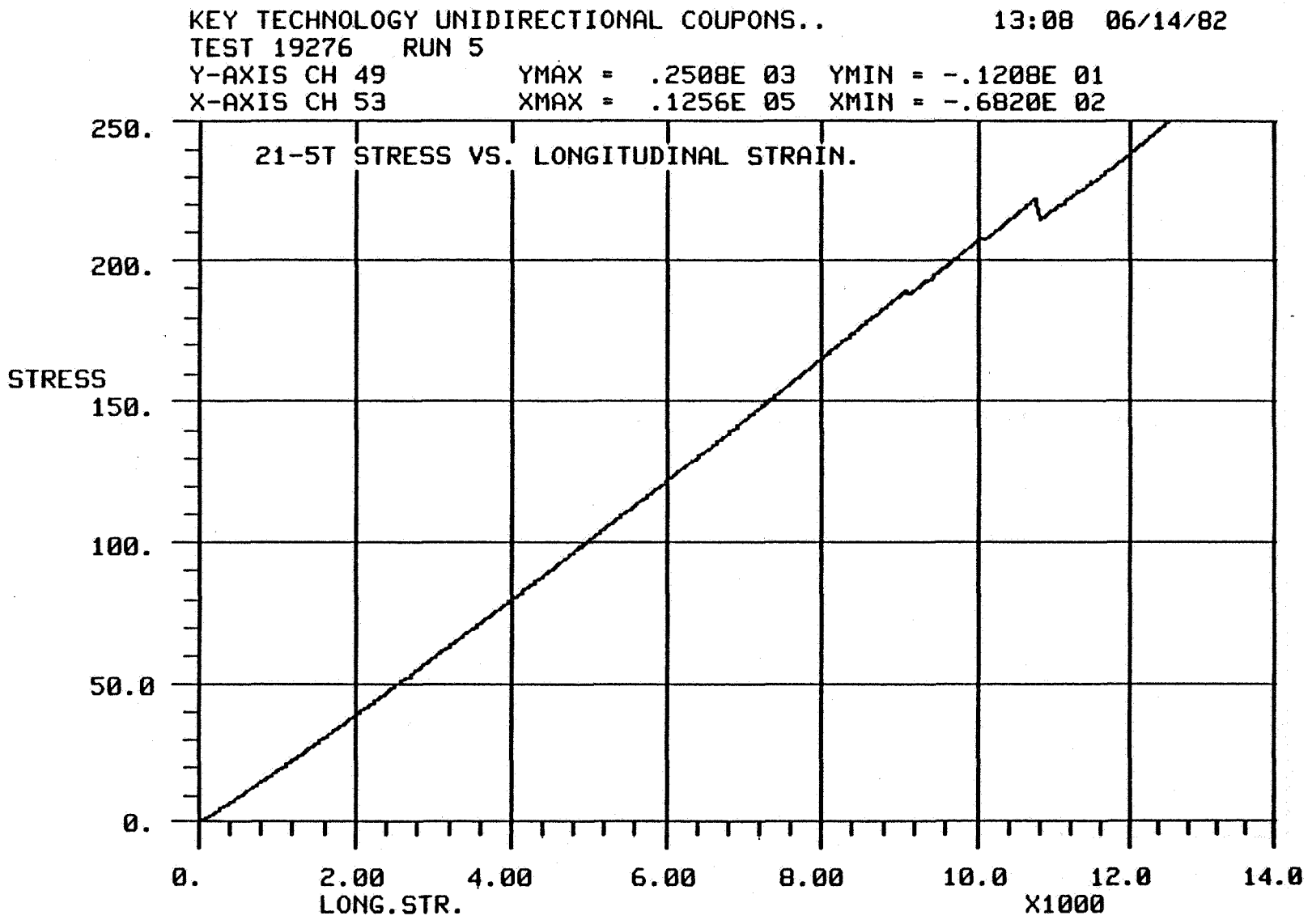

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
15:49 06/11/82
TEST 19273 RUN 4
Y-AXIS CH 49
YMAX = .2189E 03
YMIN = .1605E 01
X-AXIS CH 51
XMAX = -.2351E 02
XMIN = -.3014E 04
21-2T STRESS VS. TRANSVERSE STRAIN.
250.
200.
150.
100.
50.0
0.
STRESS
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

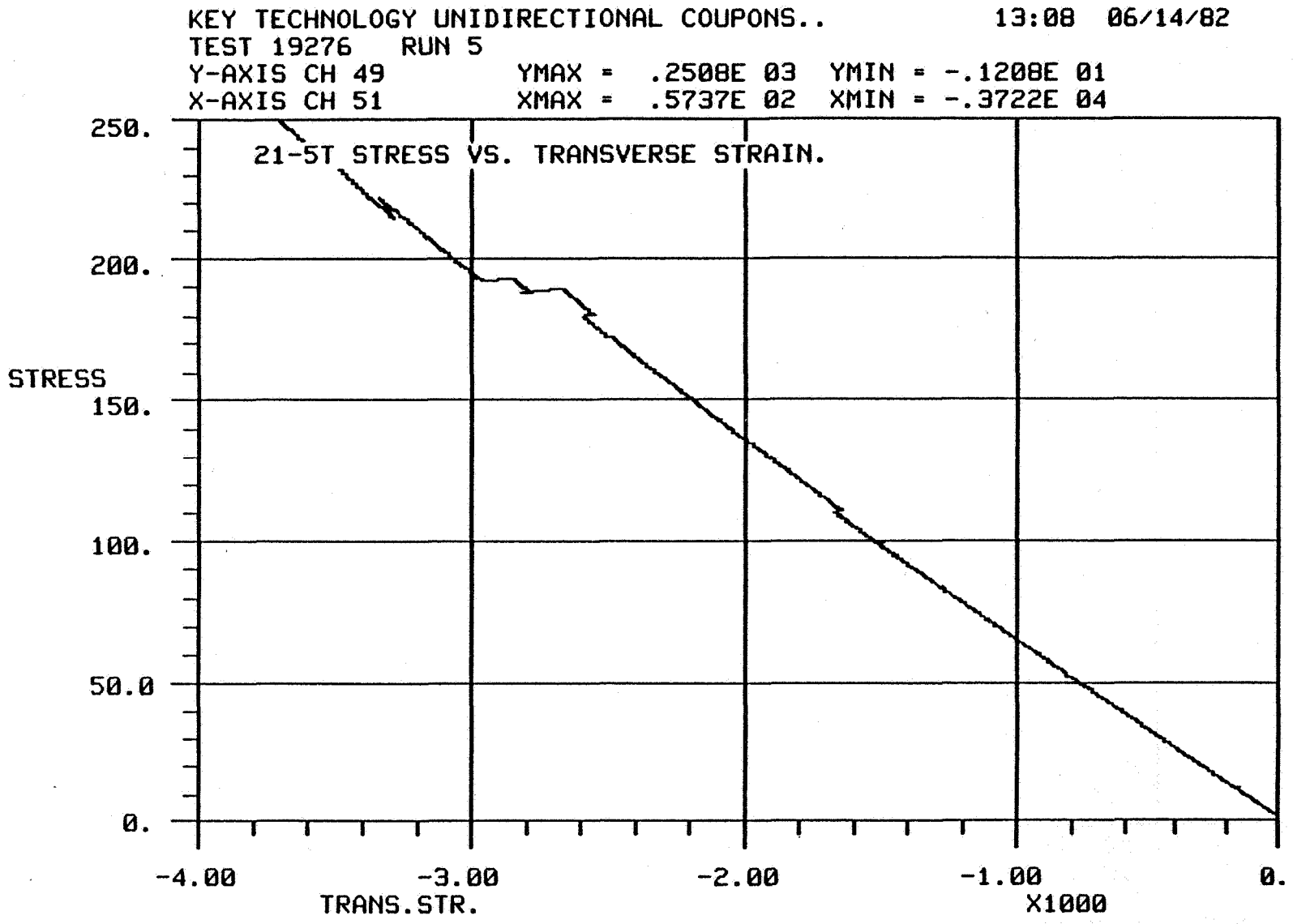

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
11:06 06/14/82
TEST 19276 RUN 2
Y-AXIS CH 49 YMAX = .2366E 03 YMIN = -.1870E 01
X-AXIS CH 53 XMAX = .1113E 05 XMIN = -.5013E 02
21-3T STRESS VS. LONGITUDINAL STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR.
X1000

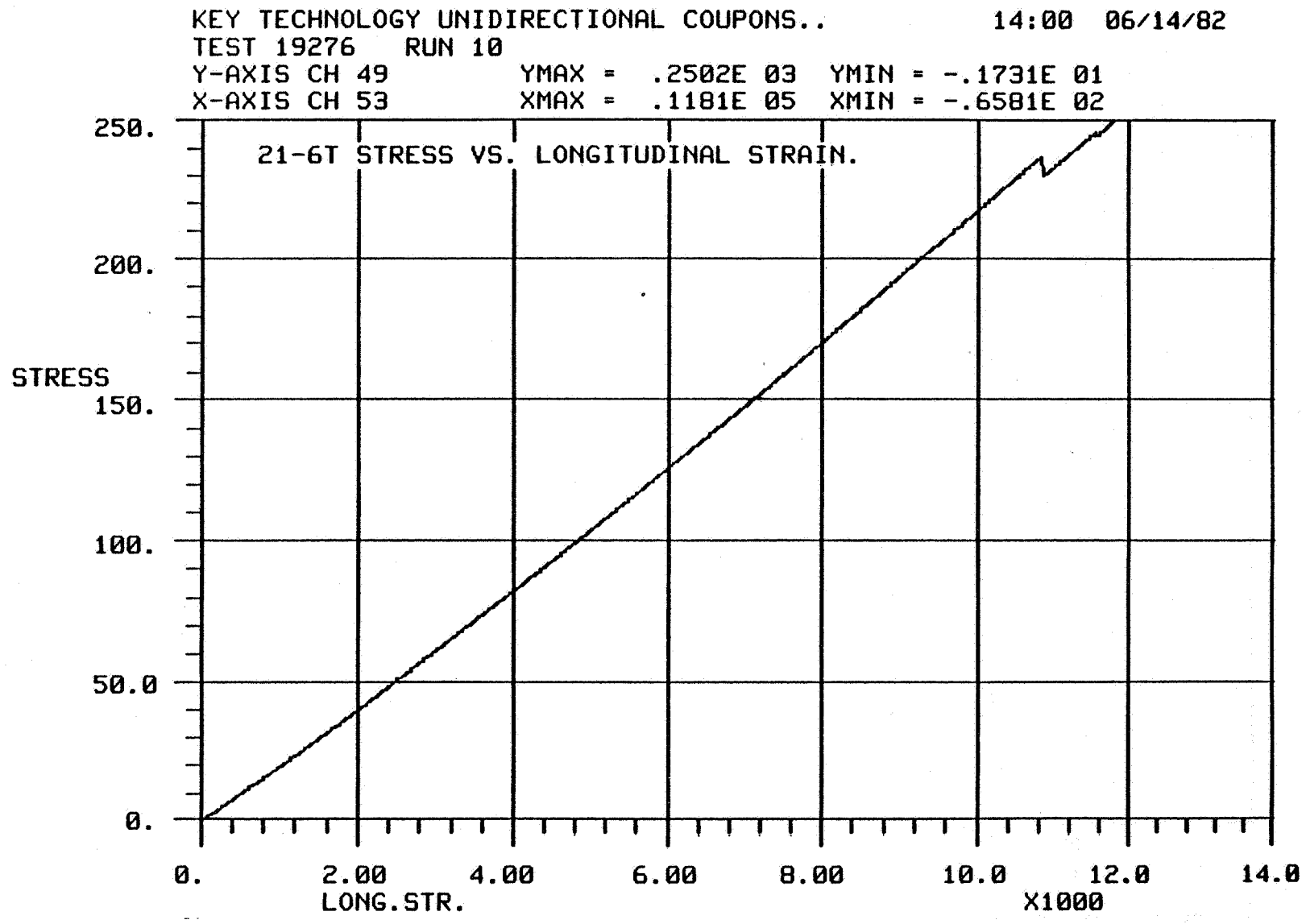

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
11:06 06/14/82
TEST 19276 RUN 2
Y-AXIS CH 49
YMAX = .2366E 03
YMIN = -.1870E 01
X-AXIS CH 51
XMAX = .3341E 01
XMIN = -.3145E 04
21-3T STRESS VS. TRANSVERSE STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

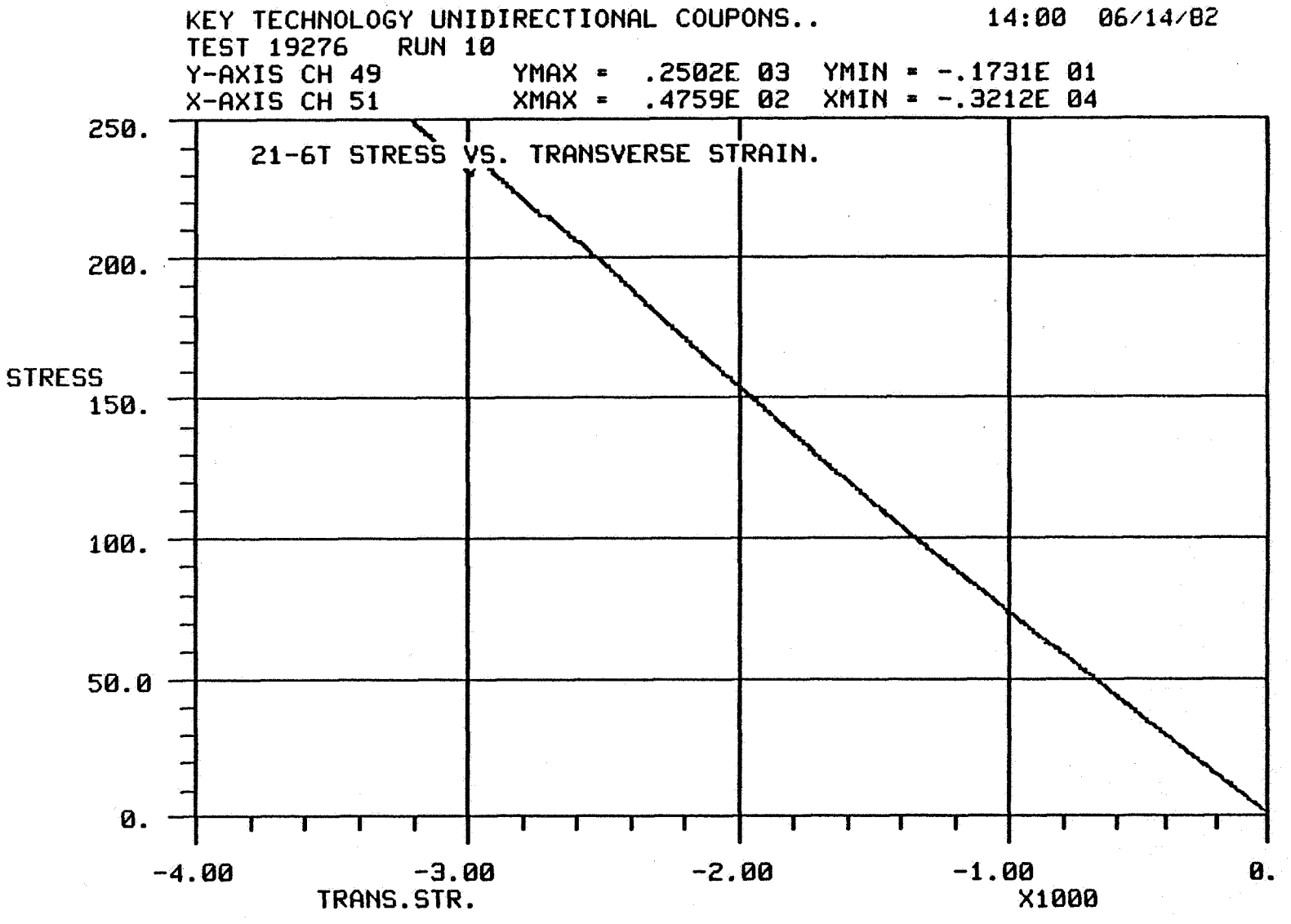

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
12:35 06/14/82
TEST 19276 RUN 4
Y-AXIS CH 49
YMAX = .2460E 03
YMIN = -.1412E 01
X-AXIS CH 53
XMAX = .1158E 05
XMIN = -.7313E 02
21-4T STRESS VS. LONGITUDINAL STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR.
X1000


KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
12:35 06/14/82
TEST 19276 RUN 4
Y-AXIS CH 49
YMAX = .2460E 03
YMIN = -.1412E 01
X-AXIS CH 51
XMAX = .2277E 02
XMIN = -.3337E 04
21-4T STRESS VS. TRANSVERSE STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000


KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
13:08 06/14/82
TEST 19276 RUN 5
Y-AXIS CH 49
YMAX = .2508E 03
YMIN = -.1208E 01
X-AXIS CH 53
XMAX = .1256E 05
XMIN = -.6820E 02
21-5T STRESS VS. LONGITUDINAL STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR.
X1000


KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
13:08 06/14/82
TEST 19276 RUN 5
Y-AXIS CH 49
YMAX = .2508E 03
YMIN = -.1208E 01
X-AXIS CH 51
XMAX = .5737E 02
XMIN = -.3722E 04
21-5T STRESS VS. TRANSVERSE STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000


KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
14:00 06/14/82
TEST 19276 RUN 10
Y-AXIS CH 49
YMAX = .2502E 03
YMIN = -.1731E 01
X-AXIS CH 53
XMAX = .1181E 05
XMIN = -.6581E 02
21-6T STRESS VS. LONGITUDINAL STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR.
X1000


KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
14:00 06/14/02
TEST 19276 RUN 10
Y-AXIS CH 49
YMAX = .2502E 03
YMIN = -.1731E 01
X-AXIS CH 51
XMAX = .4759E 02
XMIN = -.3212E 04
21-6T STRESS VS. TRANSVERSE STRAIN.
STRESS
250.
200.
150.
100.
50.0
0.
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

ORIGINAL PAGE IS
OF POOR QUALITY

TO PAUL SANDIFER | DATE 6 15 82

FROM

MODEL

LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED CORPORATION
ENGINEERS NOTEBOOK

Nº 11546-44

SUBJECT PANEL 38
KEY TECHNOLOGY UNIDIRECTIONAL
COUPONS

REF

AS4/2220-1

OP — 0 — DEGREE
25000 #/10 VOLTS × 1T 1350-2450
20000με/10 VOLTS × 2T 1330-2450
20000με/10 VOLTS × 3T 1540-2650
= 4T 1480-2600
× 5T 1480-2650
· 6T 1250-2400

LOCATION	I.D. 38-1T	38-2T	SAME 38-3T	42.806 39-4T	44404 38-5T	42.177 38-6T
1	0.0579	0.0597	0.0583	0.0589	0.0555	0.0577
2	0.0598	0.0593	0.0592	0.0585	0.0558	0.0573
3	0.0575	0.0582	0.0579	0.0582	0.0555	0.0573
4	0.0581	0.0572	0.0579	0.0567	0.0557	0.0567
5	0.0586	0.0587	0.0583	0.0570	0.0567	0.0580
6	0.0582	0.0574	0.0582	0.0579	0.0562	0.0577
AVE	0.0584	0.0583	0.0583	0.0579	0.0559	0.0574
7	1.0090	1.0087	1.0092	1.0090	1.0080	1.0081
8	1.0090	1.0087	1.0090	1.0090	1.0073	1.0082
9	1.0090	1.0087	1.0090	1.0092	1.0067	1.0082
AVE	1.0090	1.0087	1.0090	1.0091	1.0073	1.0082
TEST RUN	19309/3	19309/3	19309/4	19317/1	19327/2	19325/1
LOAD #	1 121.0	1 121.0	1 121.0	1 121.0	1 120.7	1 120.9
AREA	0.0589	0.0588	0.0588	0.0584	0.0562	0.0579

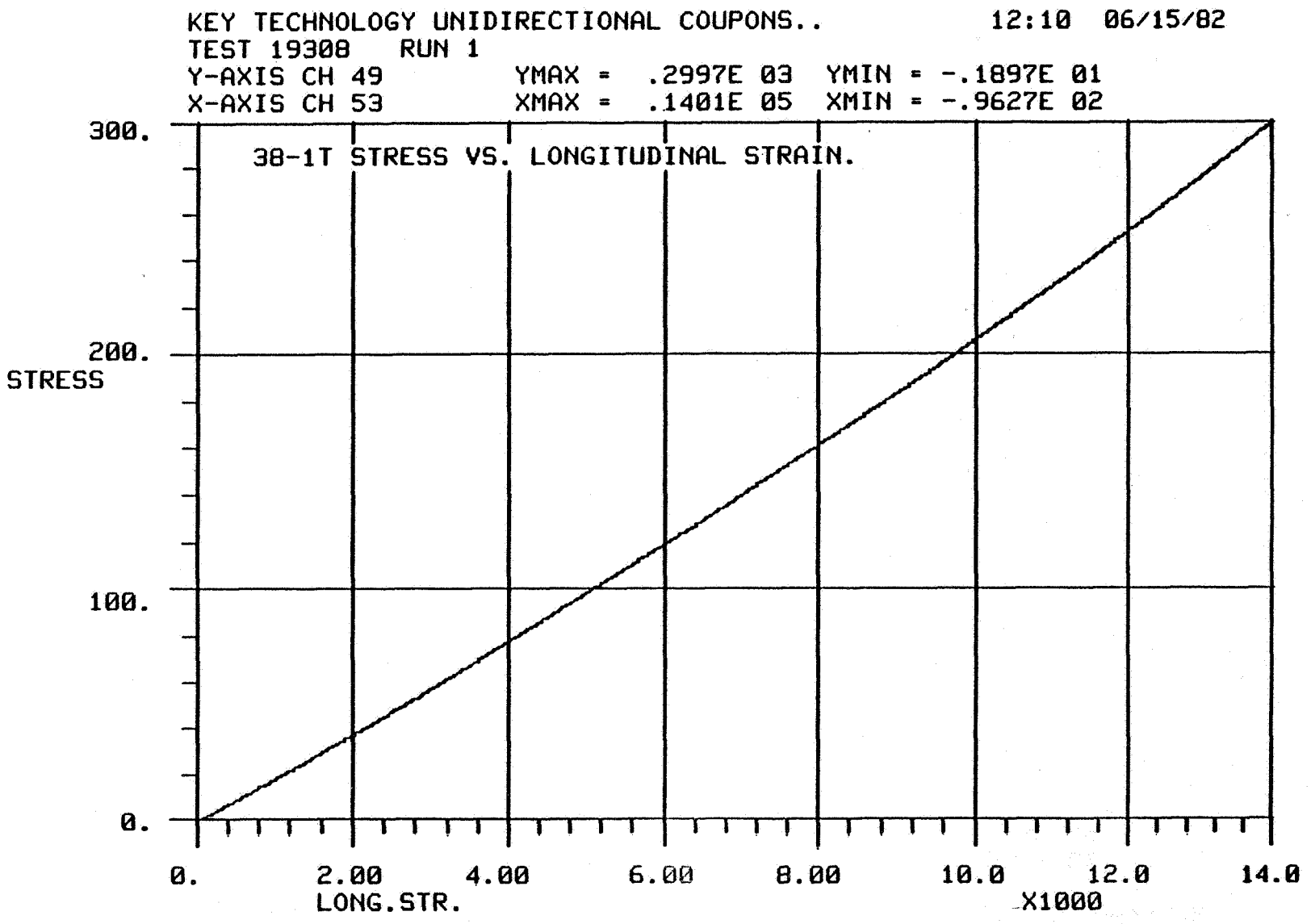
42.444 42.517

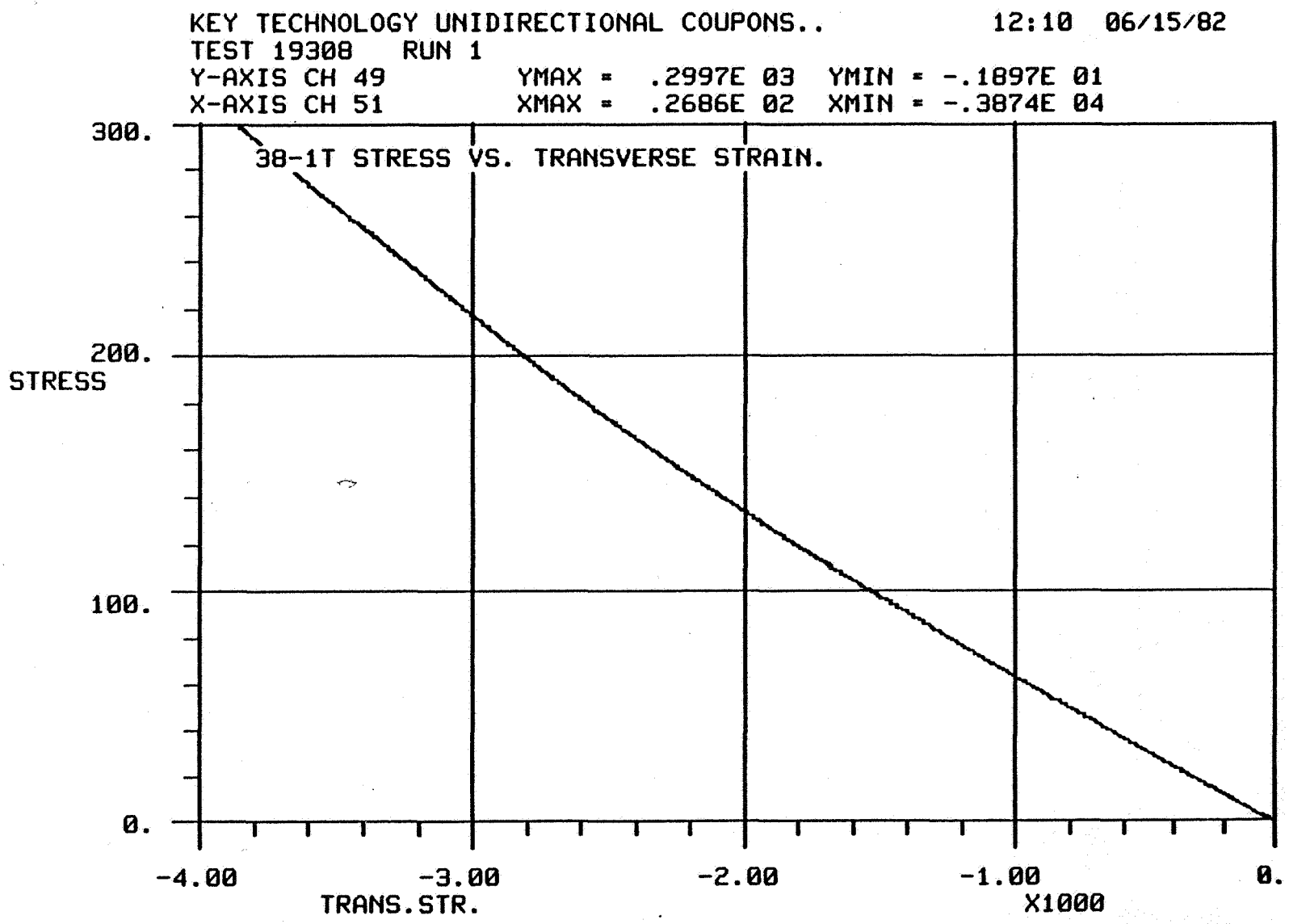
$\mu\varepsilon_1 = \frac{121.0 \times 10^6}{2.075(50121.0)} = 1163$ 69: 3:51 TRANS ε

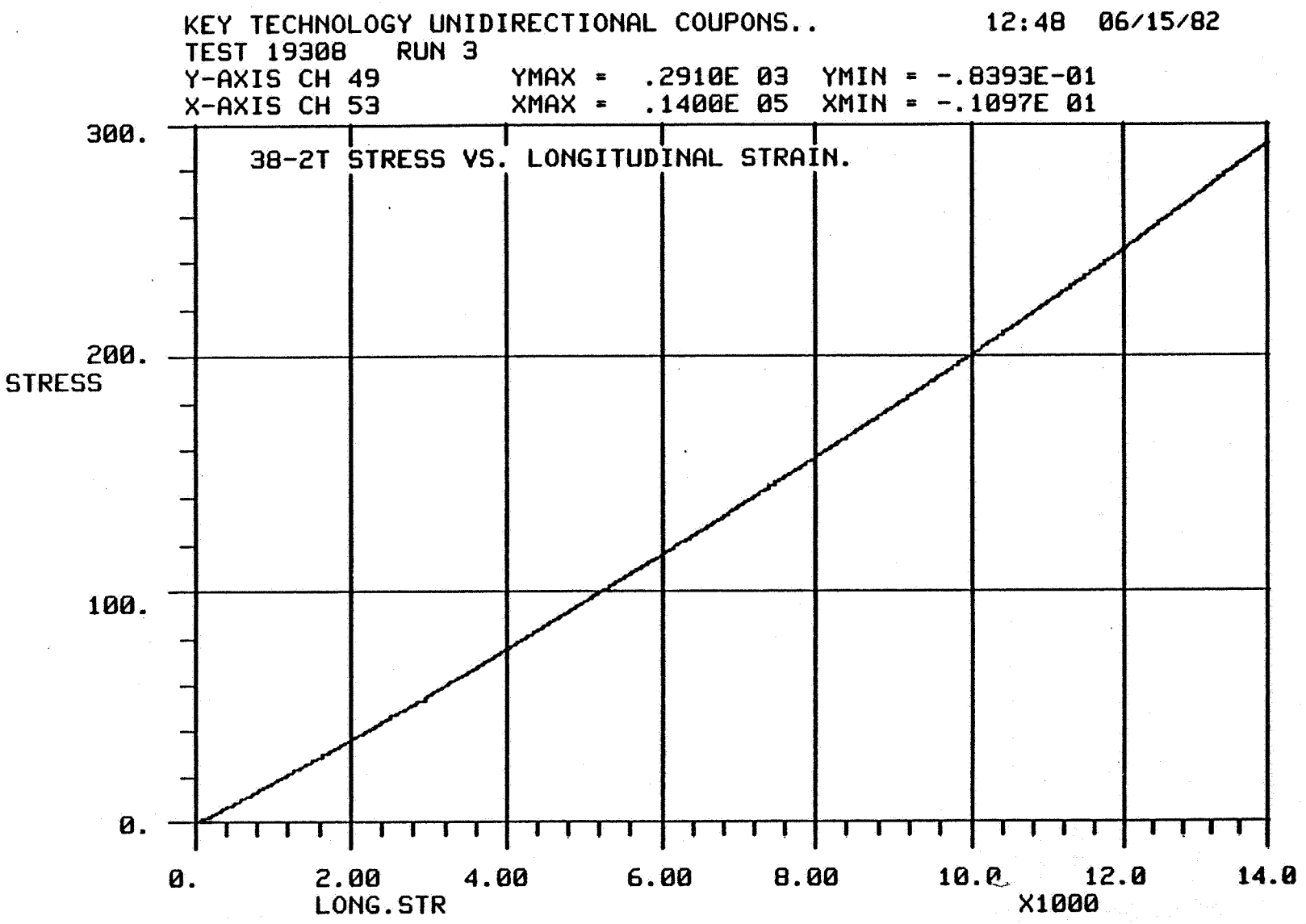
$\mu\varepsilon_2 = \frac{121.0 \times 10^6}{2.095(50121.0)} = 1157.3$ 70: 4:53 LONG ε

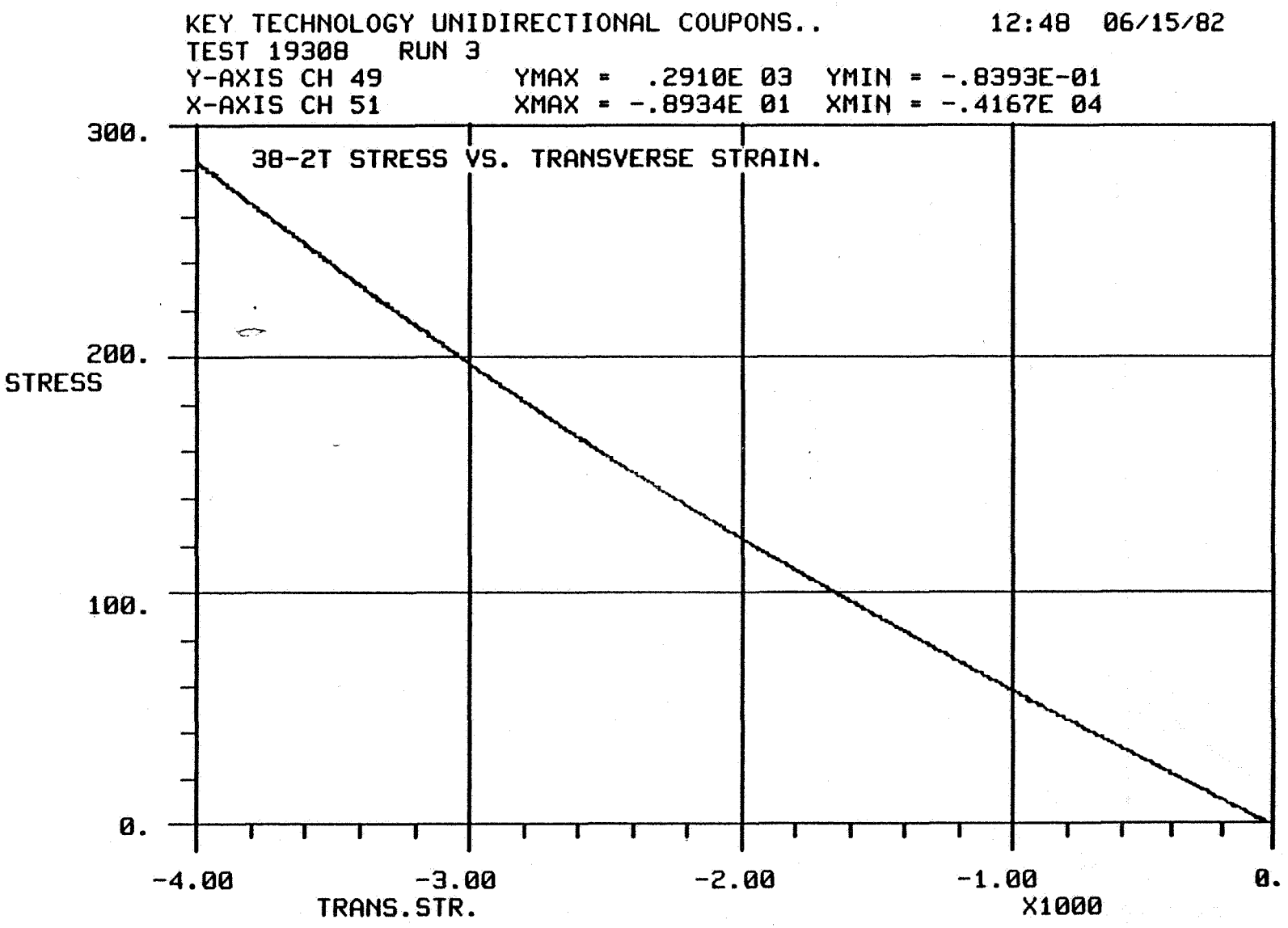
3/51 4/9 LOAD

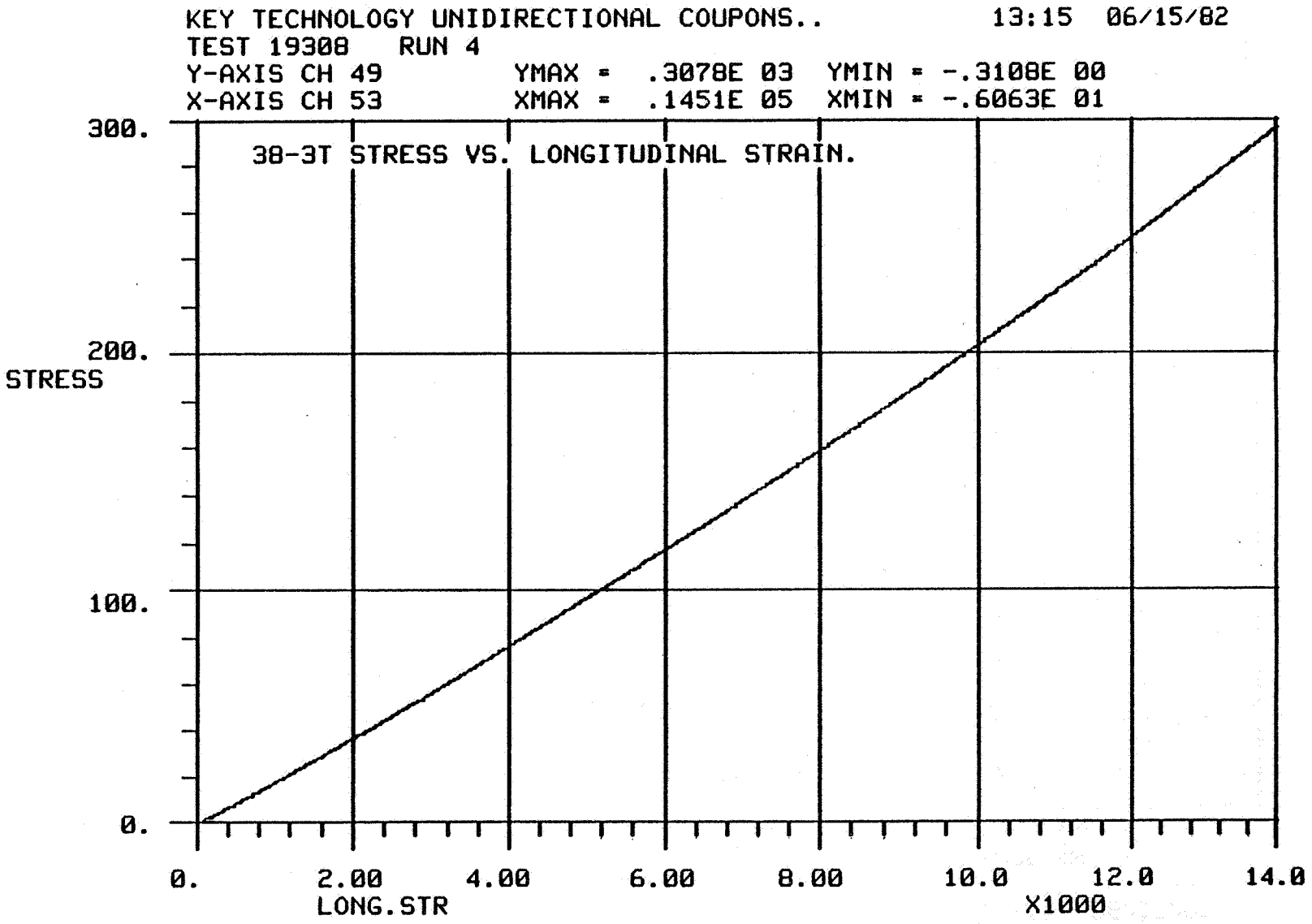
CONTINUED ON SHEET NO.

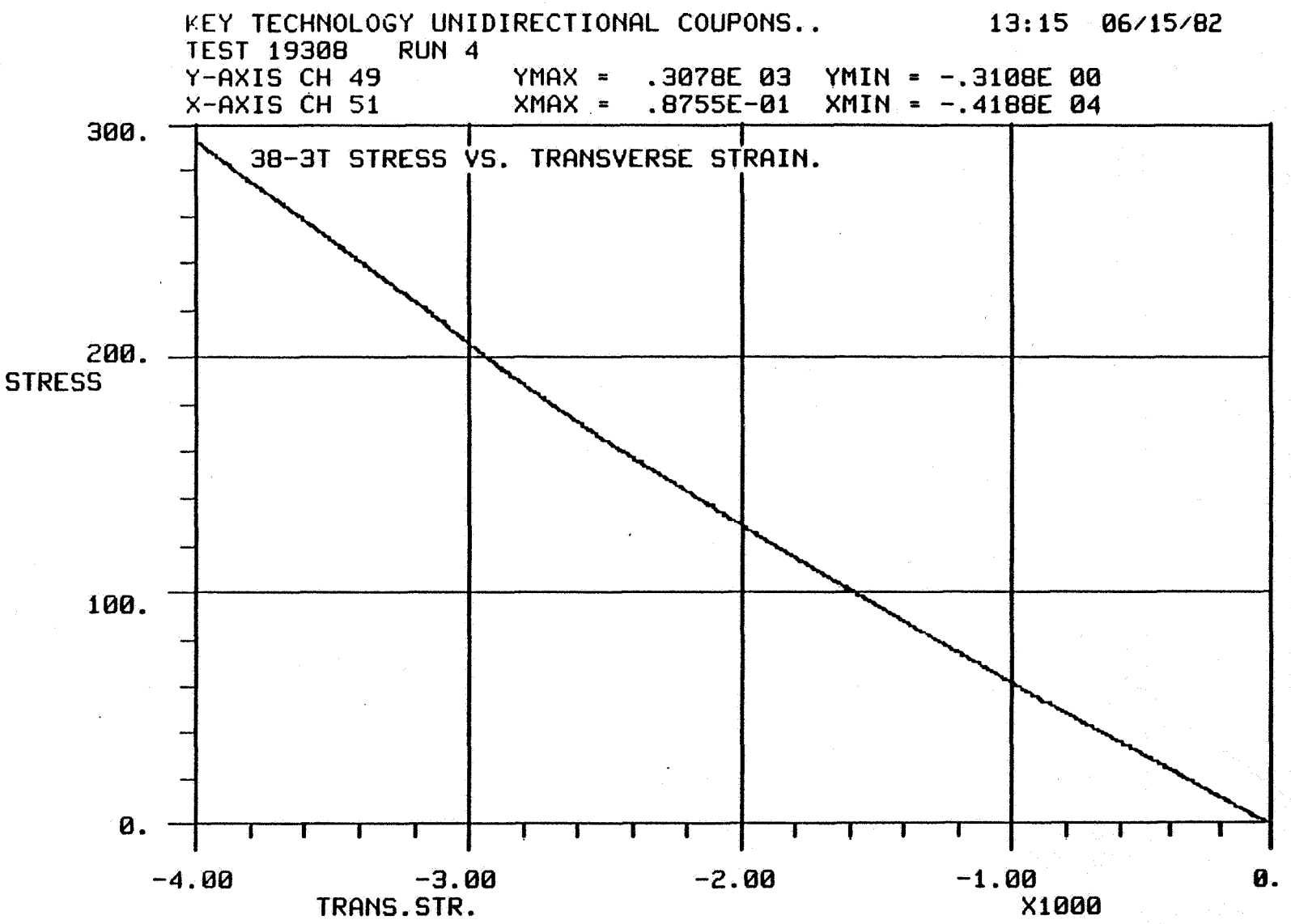

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
12:10 06/15/82
TEST 19308 RUN 1
Y-AXIS CH 49
YMAX = .2997E 03
YMIN = -.1897E 01
X-AXIS CH 53
XMAX = .1401E 05
XMIN = -.9627E 02
38-1T STRESS VS. LONGITUDINAL STRAIN.
300.
200.
100.
0.
STRESS
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR.
X1000

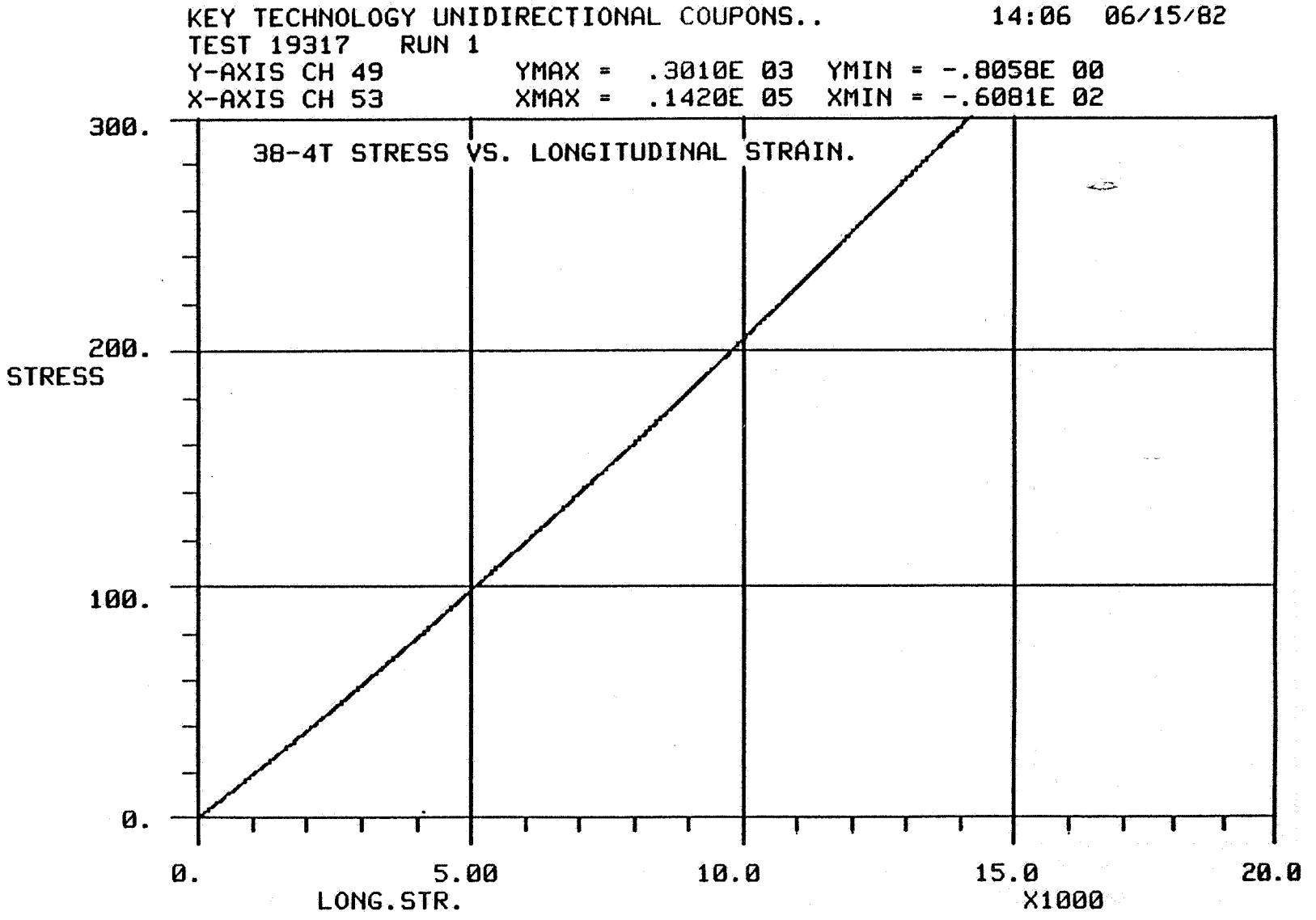

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
12:10 06/15/82
TEST 19308 RUN 1
Y-AXIS CH 49
YMAX = .2997E 03
YMIN = -.1897E 01
X-AXIS CH 51
XMAX = .2686E 02
XMIN = -.3874E 04
38-1T STRESS VS. TRANSVERSE STRAIN.
300.
200.
100.
0.
STRESS
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

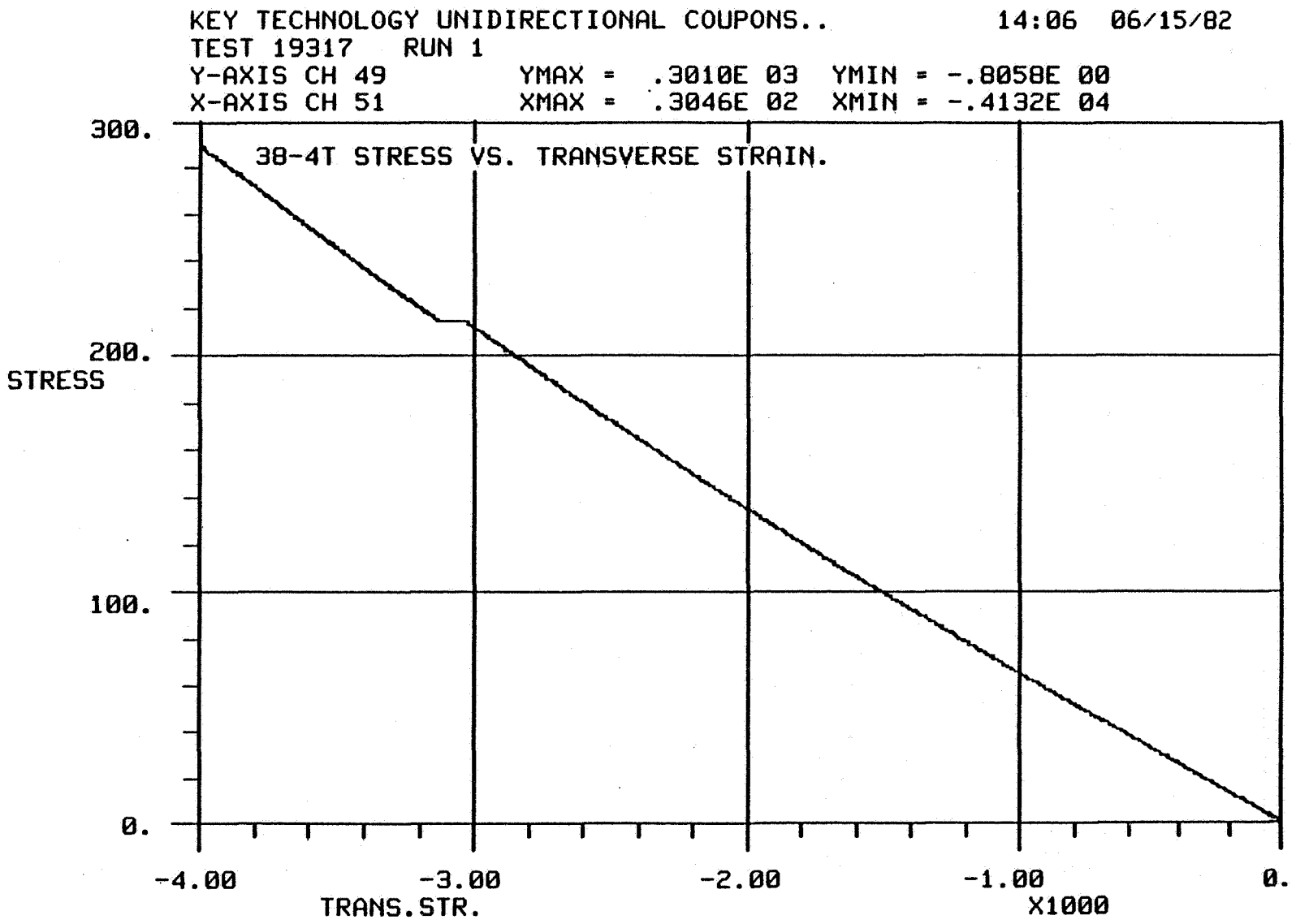

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
12:48 06/15/82
TEST 19308 RUN 3
Y-AXIS CH 49
YMAX = .2910E 03
YMIN = -.8393E-01
X-AXIS CH 53
XMAX = .1400E 05
XMIN = -.1097E 01
38-2T STRESS VS. LONGITUDINAL STRAIN.
300.
200.
100.
0.
STRESS
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR
X1000

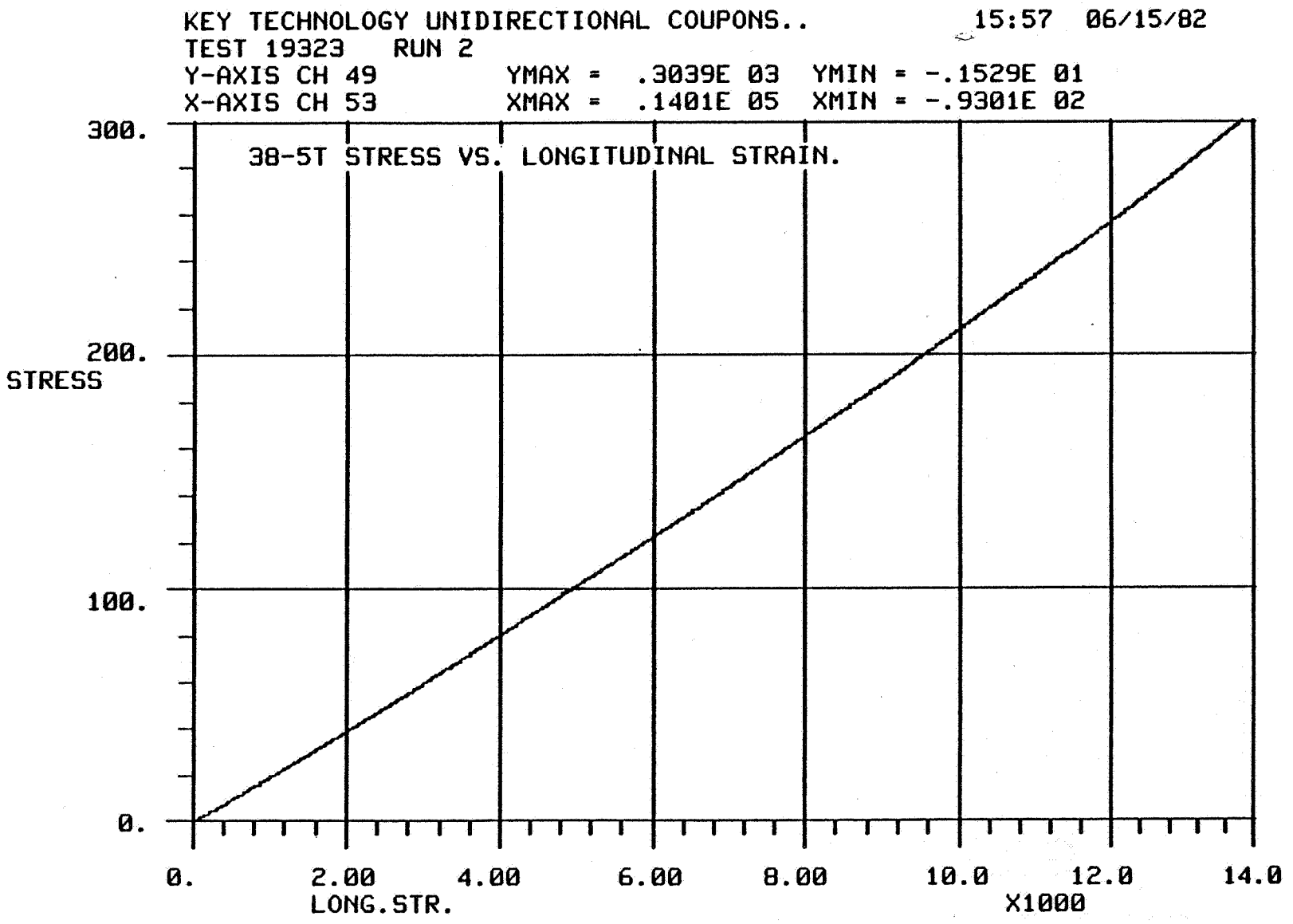

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
12:48 06/15/82
TEST 19308 RUN 3
Y-AXIS CH 49
YMAX = .2910E 03
YMIN = -.8393E-01
X-AXIS CH 51
XMAX = -.8934E 01
XMIN = -.4167E 04
38-2T STRESS VS. TRANSVERSE STRAIN.
300.
200.
100.
0.
STRESS
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

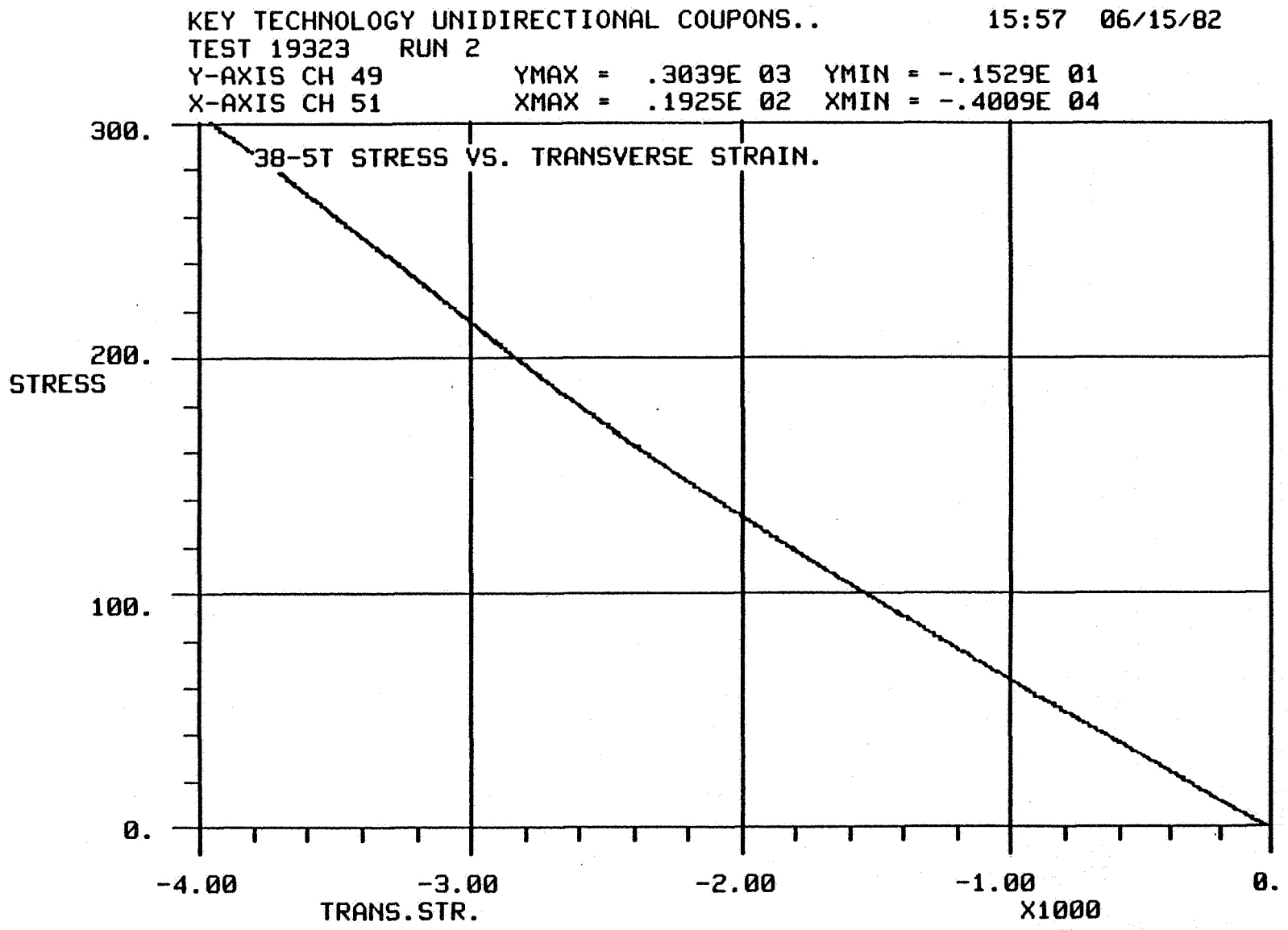

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
13:15 06/15/82
TEST 19308 RUN 4
Y-AXIS CH 49
YMAX = .3078E 03
YMIN = -.3108E 00
X-AXIS CH 53
XMAX = .1451E 05
XMIN = -.6063E 01
38-3T STRESS VS. LONGITUDINAL STRAIN.
300.
200.
100.
0.
STRESS
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR
X1000

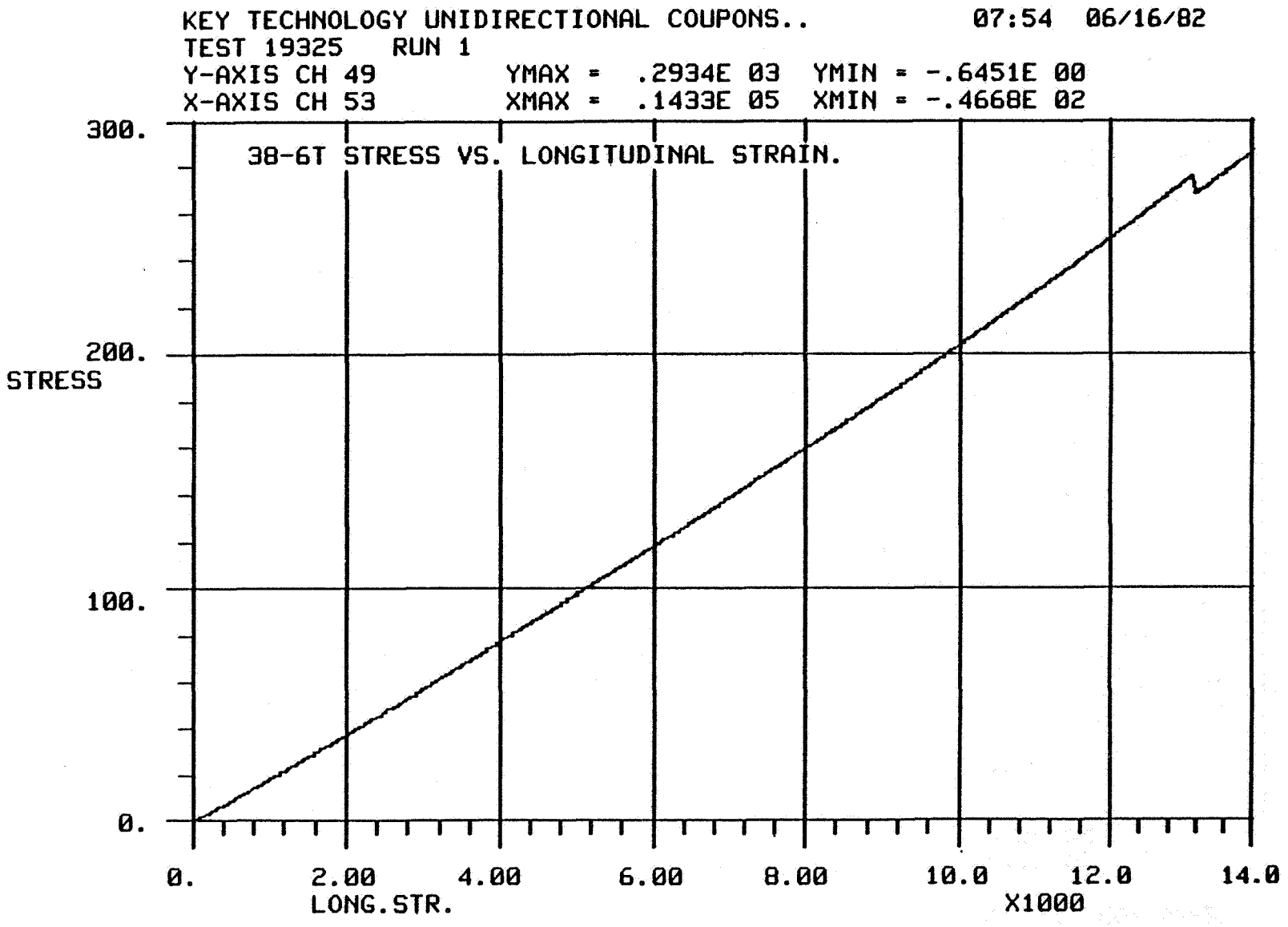

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
13:15 06/15/82
TEST 19308 RUN 4
Y-AXIS CH 49
YMAX = .3078E 03
YMIN = -.3108E 00
X-AXIS CH 51
XMAX = .8755E-01
XMIN = -.4188E 04
38-3T STRESS VS. TRANSVERSE STRAIN.
300.
200.
100.
0.
STRESS
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

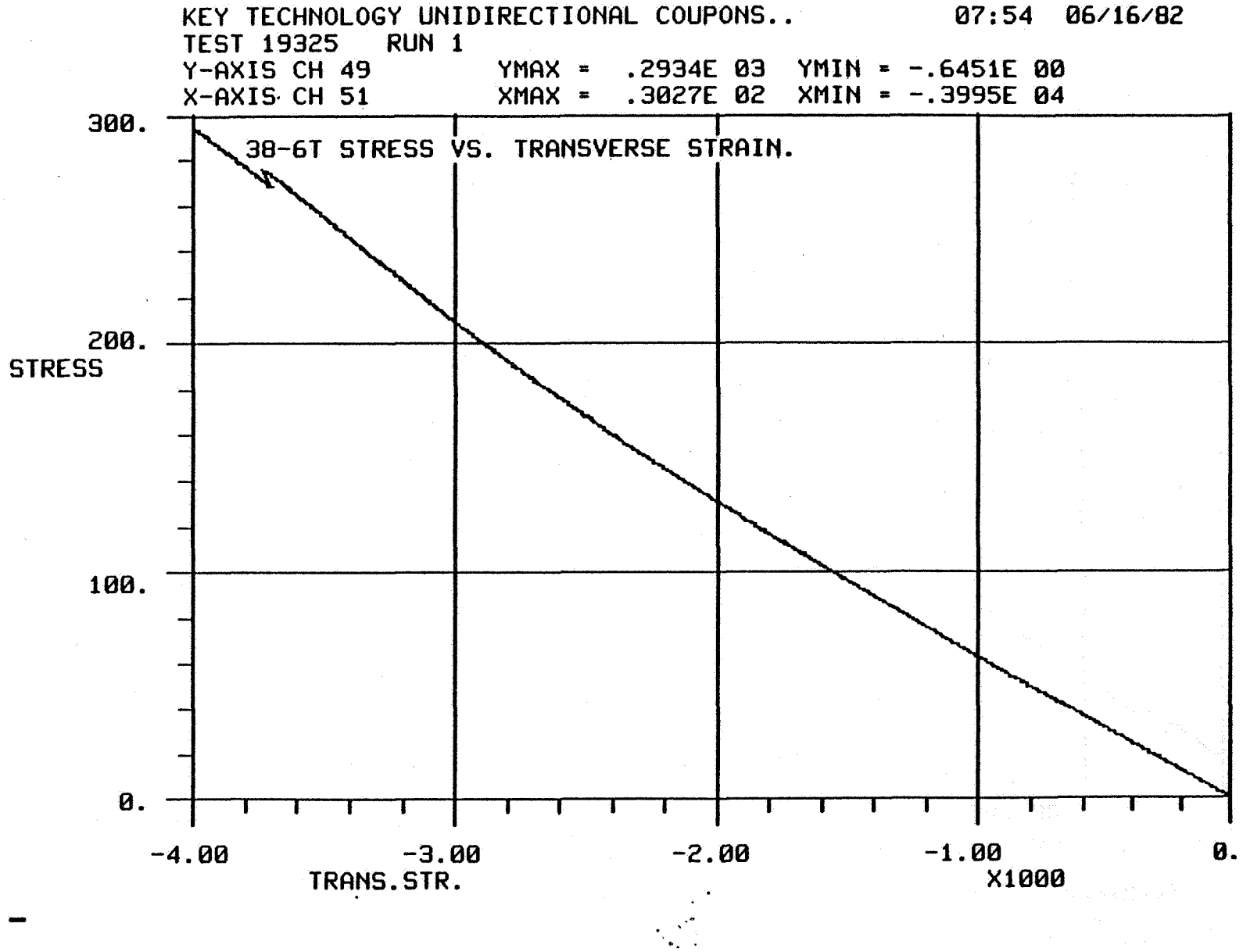

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
14:06 06/15/82
TEST 19317 RUN 1
Y-AXIS CH 49 YMAX = .3010E 03 YMIN = -.8058E 00
X-AXIS CH 53 XMAX = .1420E 05 XMIN = -.6081E 02
38-4T STRESS VS. LONGITUDINAL STRAIN.
300.
200.
100.
0.
STRESS
0.
5.00
10.0
15.0
20.0
LONG.STR.
X1000


KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
14:06 06/15/82
TEST 19317 RUN 1
Y-AXIS CH 49
YMAX = .3010E 03
YMIN = -.8058E 00
X-AXIS CH 51
XMAX = .3046E 02
XMIN = -.4132E 04
38-4T STRESS VS. TRANSVERSE STRAIN.
300.
200.
100.
0.
STRESS
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

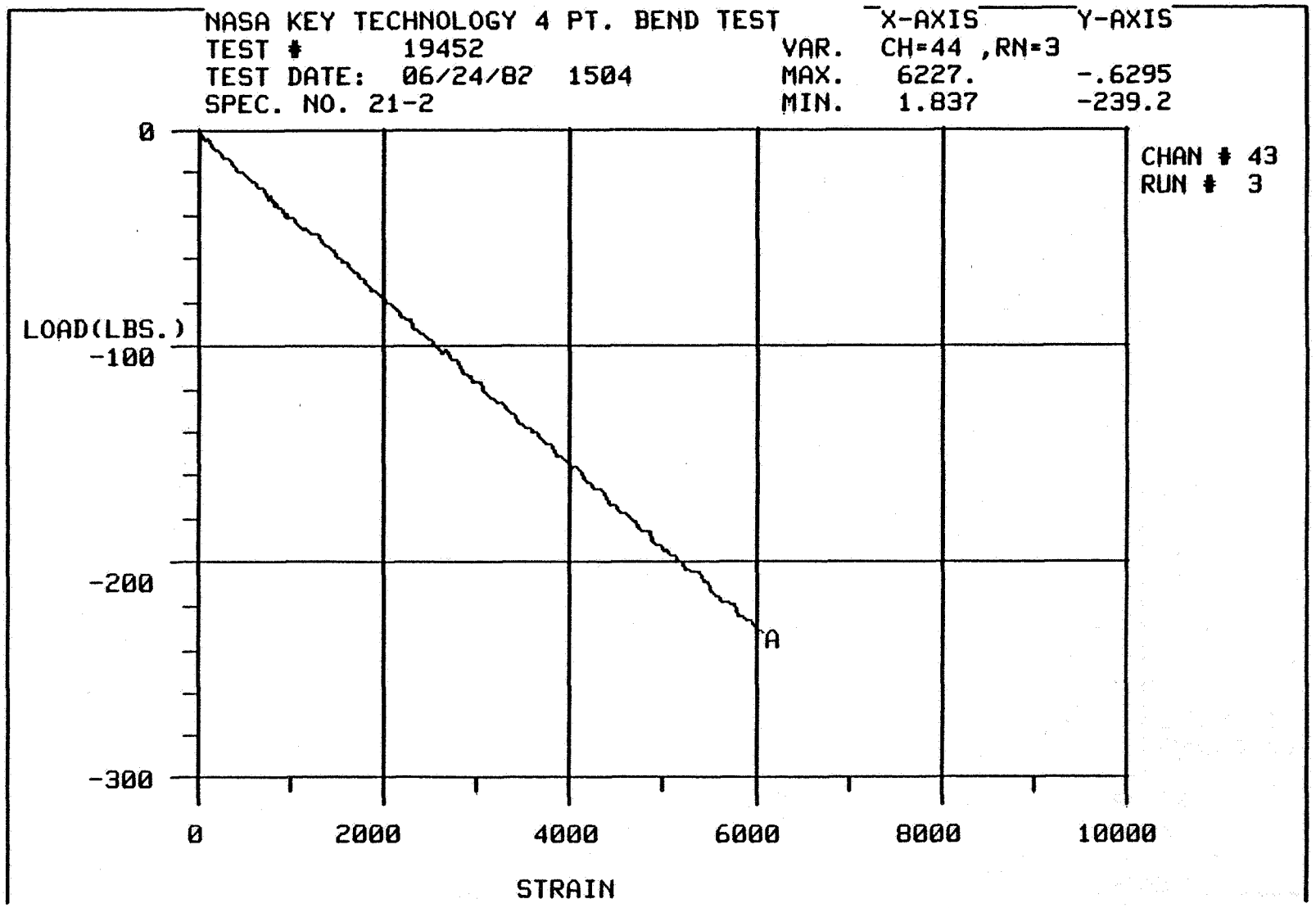

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
15:57 06/15/82
TEST 19323 RUN 2
Y-AXIS CH 49
YMAX = .3039E 03
YMIN = -.1529E 01
X-AXIS CH 53
XMAX = .1401E 05
XMIN = -.9301E 02
38-5T STRESS VS. LONGITUDINAL STRAIN.
300.
200.
100.
0.
STRESS
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR.
X1000

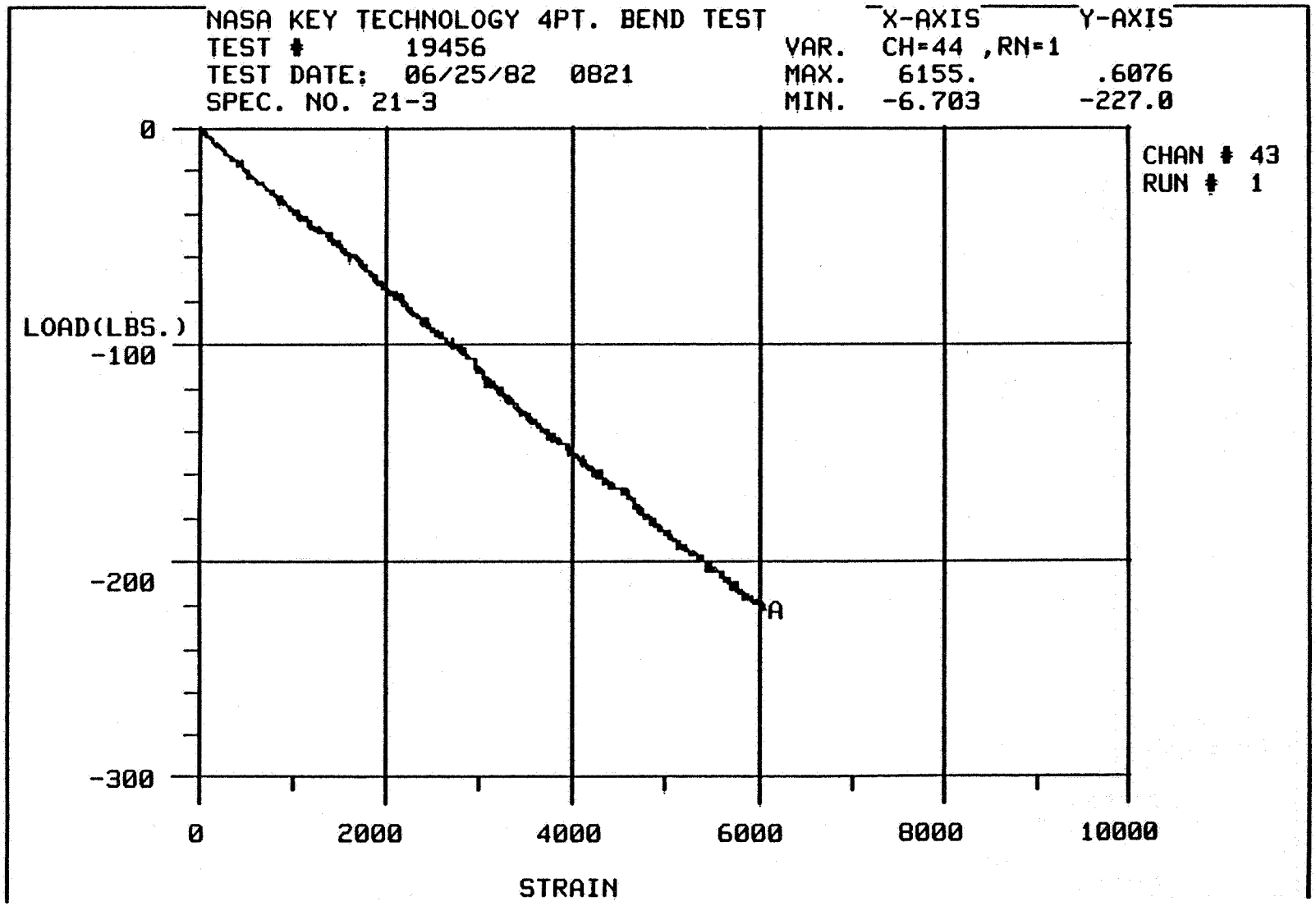

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
15:57 06/15/82
TEST 19323 RUN 2
Y-AXIS CH 49
YMAX = .3039E 03
YMIN = -.1529E 01
X-AXIS CH 51
XMAX = .1925E 02
XMIN = -.4009E 04
38-5T STRESS VS. TRANSVERSE STRAIN.
300.
200.
100.
0.
STRESS
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

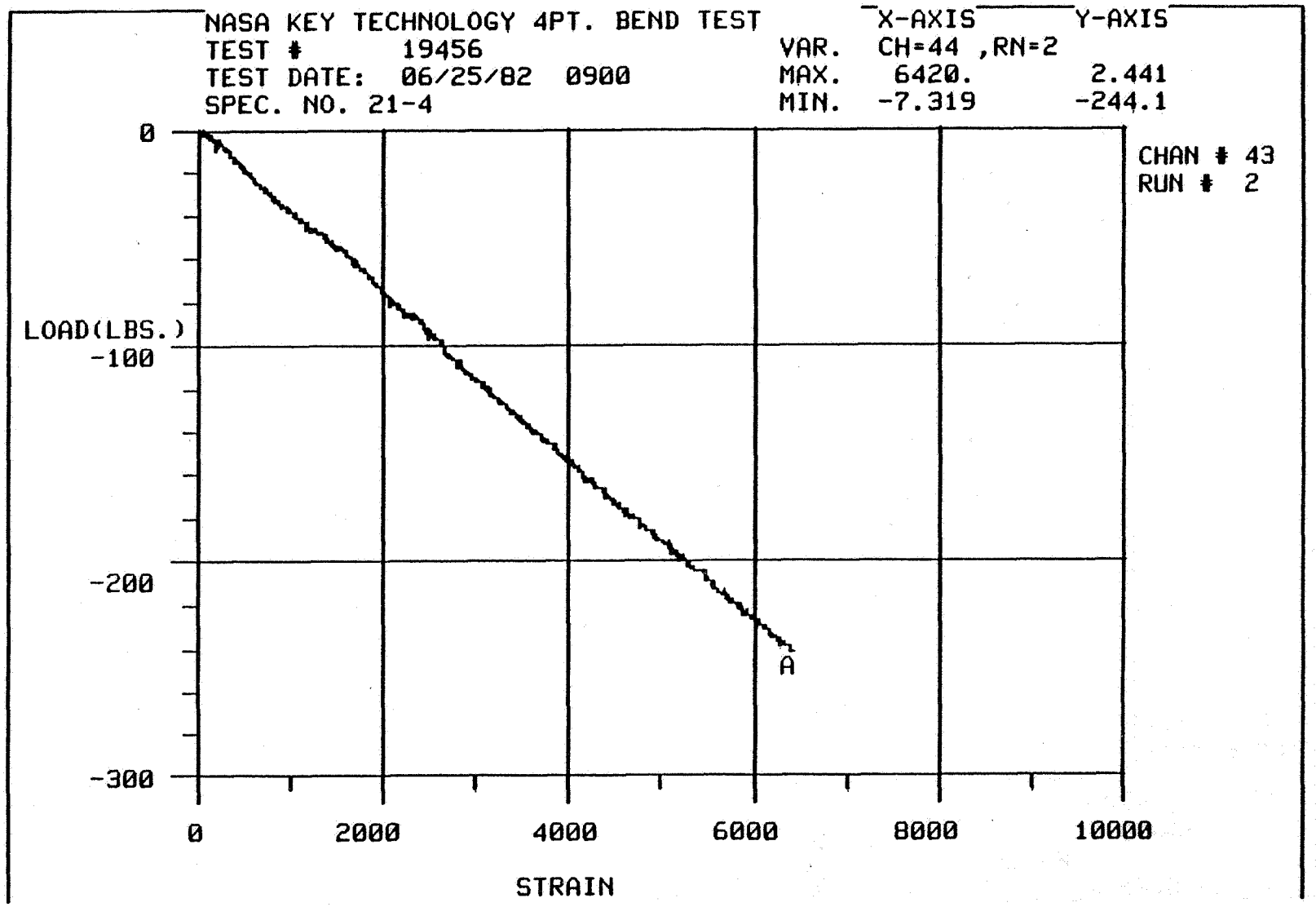

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
07:54 06/16/82
TEST 19325 RUN 1
Y-AXIS CH 49
YMAX = .2934E 03
YMIN = -.6451E 00
X-AXIS CH 53
XMAX = .1433E 05
XMIN = -.4668E 02
38-6T STRESS VS. LONGITUDINAL STRAIN.
300.
200.
100.
0.
STRESS
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
LONG.STR.
X1000

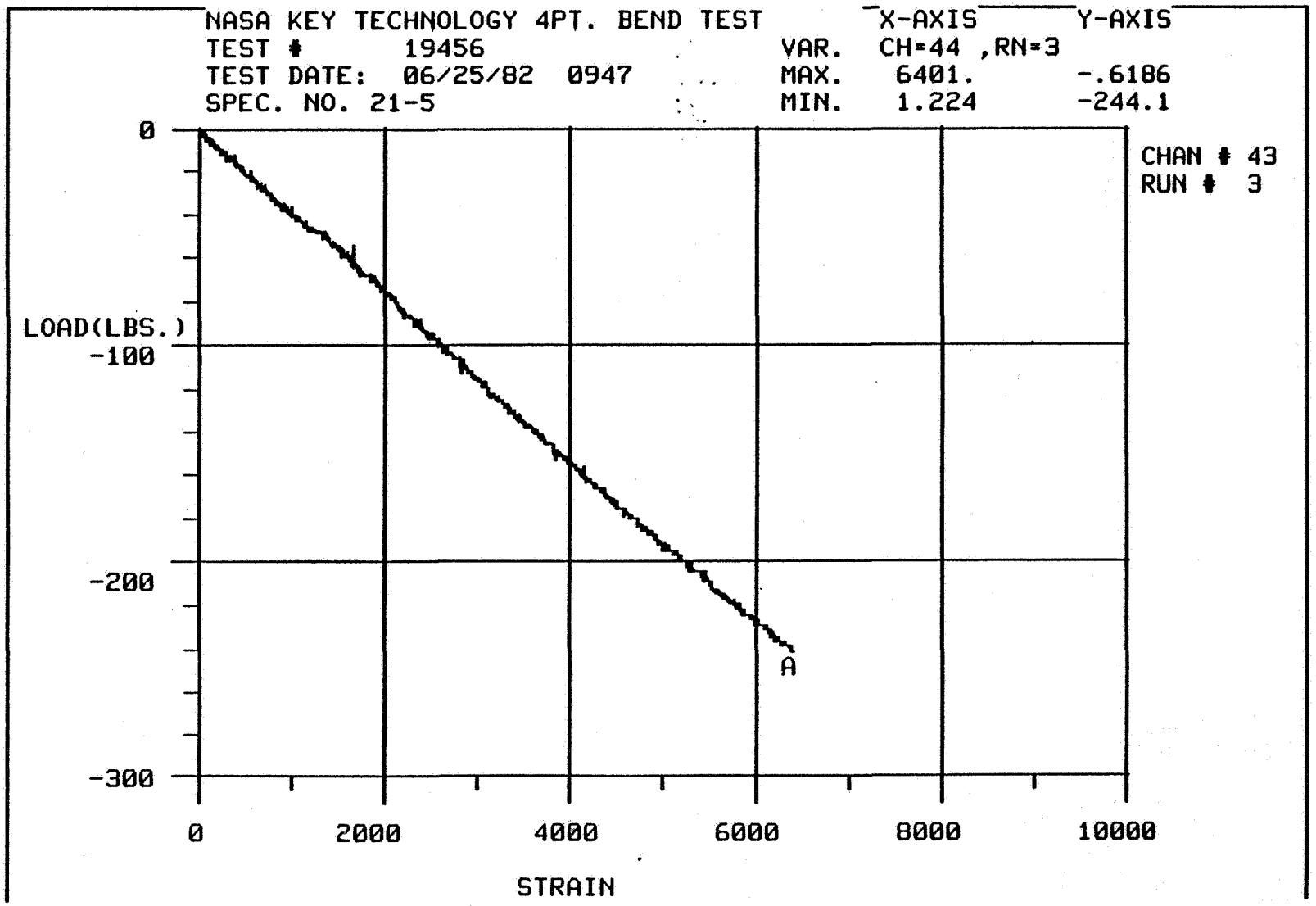

KEY TECHNOLOGY UNIDIRECTIONAL COUPONS..
07:54 06/16/82
TEST 19325 RUN 1
Y-AXIS CH 49
YMAX = .2934E 03
YMIN = -.6451E 00
X-AXIS CH 51
XMAX = .3027E 02
XMIN = -.3995E 04
38-6T STRESS VS. TRANSVERSE STRAIN.
300.
200.
100.
0.
STRESS
-4.00
-3.00
-2.00
-1.00
0.
TRANS.STR.
X1000

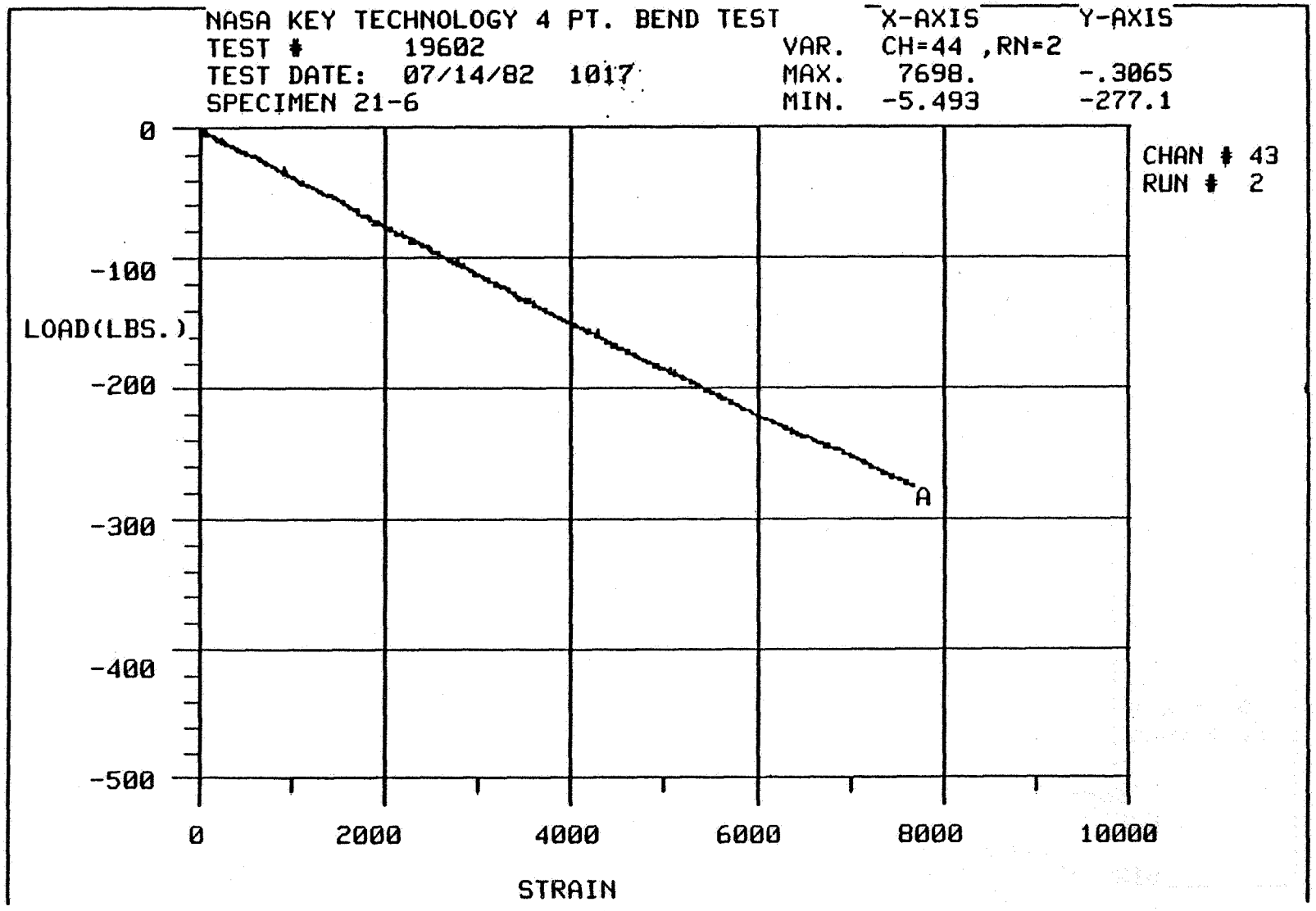
APPENDIX B6

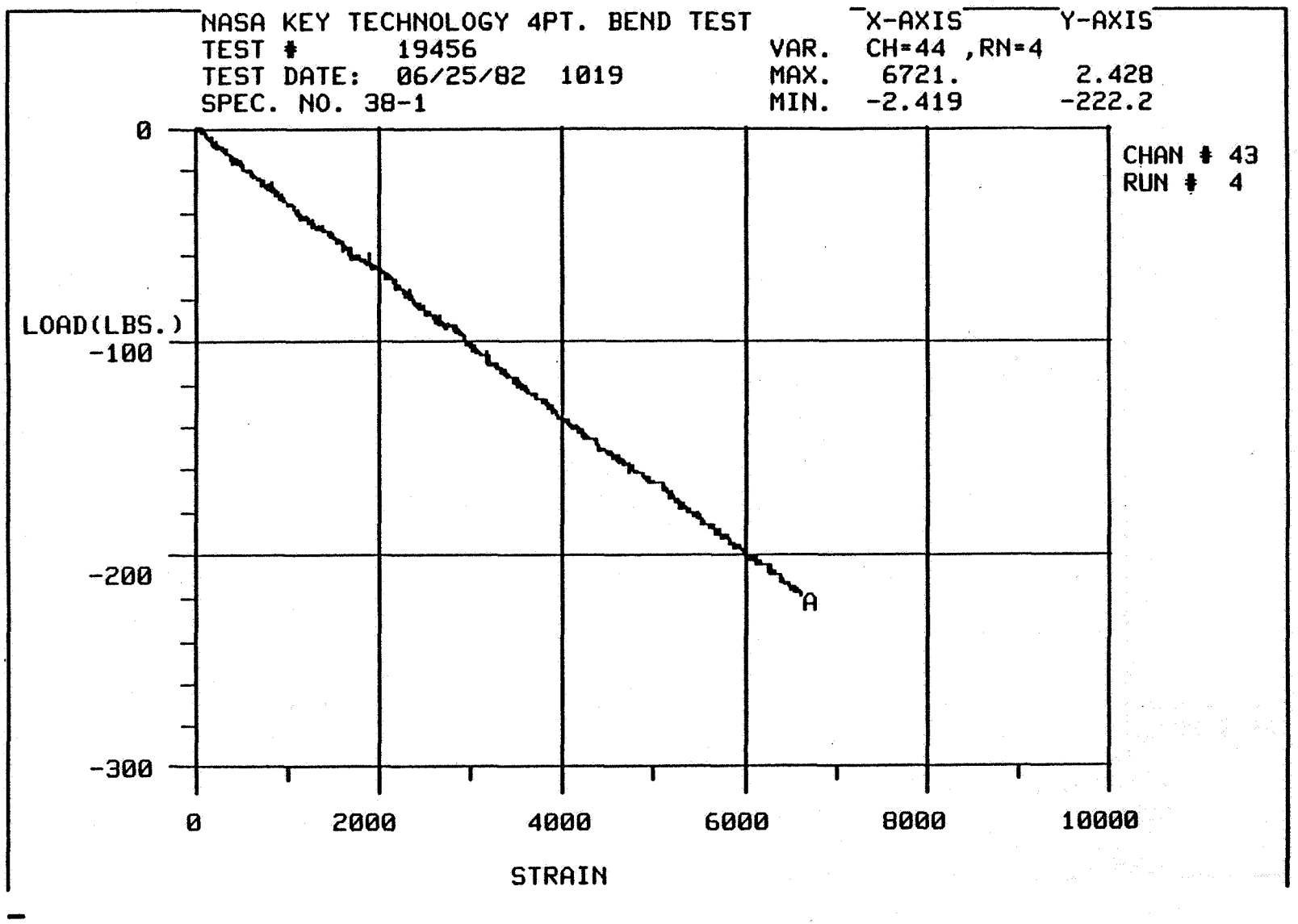

NASA KEY TECHNOLOGY 4 PT. BEND TEST
TEST # 19452
TEST DATE: 06/24/82 1504
SPEC. NO. 21-2
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=3
MAX. 6227. -.6295
MIN. 1.837 -239.2
CHAN # 43
RUN # 3
LOAD(LBS.)
0
-100
-200
-300
0
2000
4000
6000
8000
10000
STRAIN
A

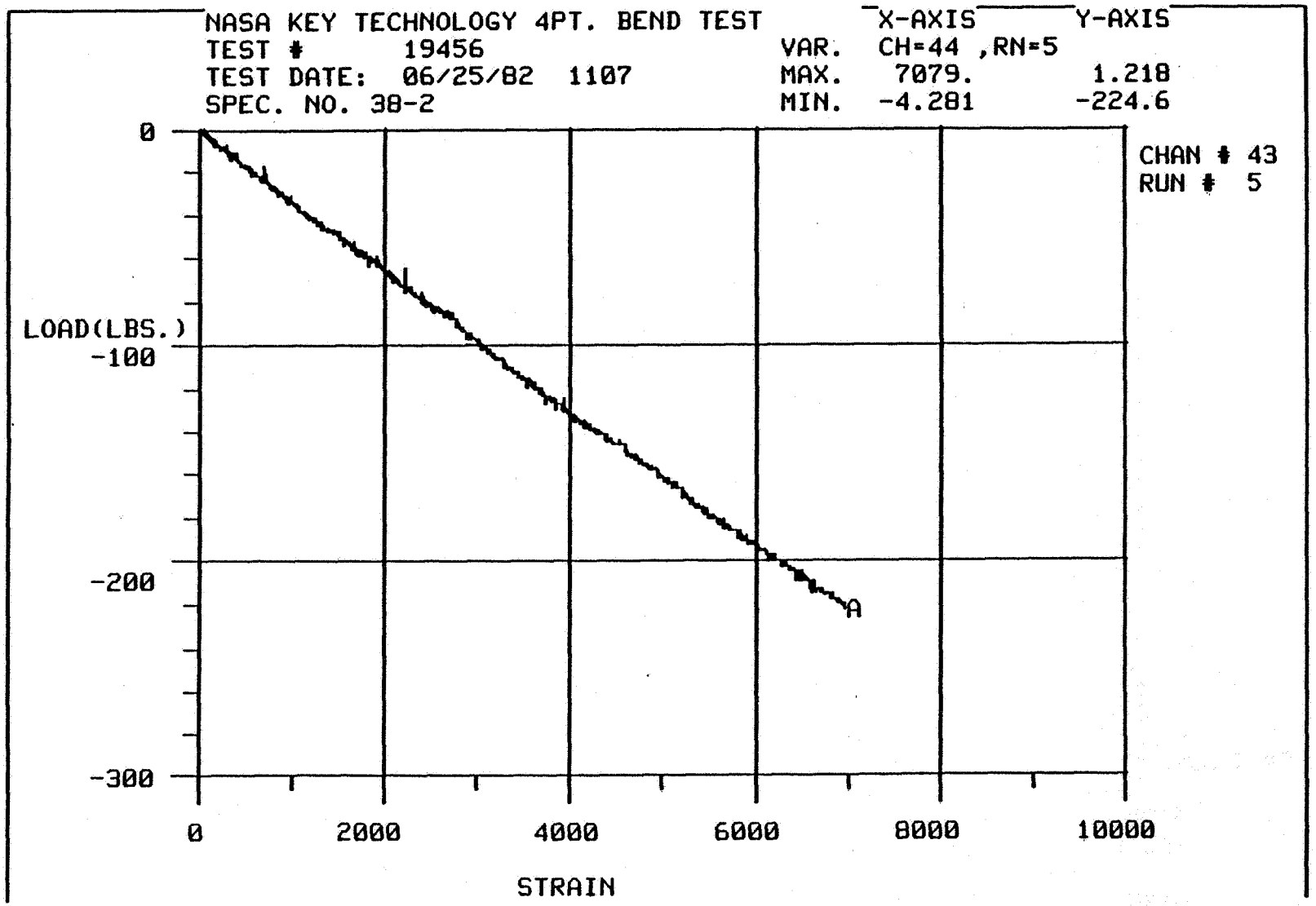

NASA KEY TECHNOLOGY 4PT. BEND TEST
TEST # 19456
TEST DATE: 06/25/82 0821
SPEC. NO. 21-3
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=1
MAX. 6155. .6076
MIN. -6.703 -227.0
CHAN # 43
RUN # 1
LOAD(LBS.)
0
-100
-200
-300
A
0
2000
4000
6000
8000
10000
STRAIN

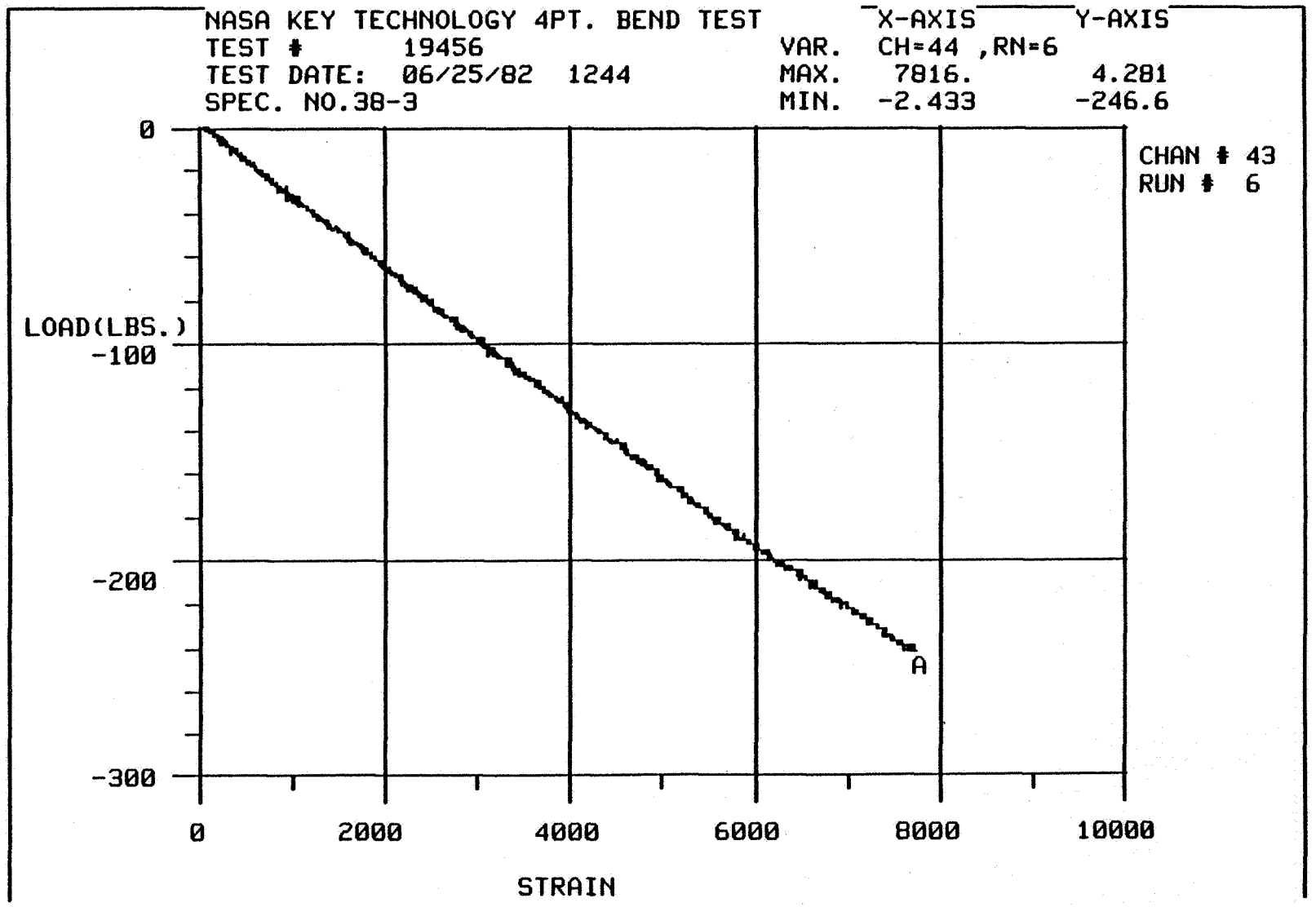

NASA KEY TECHNOLOGY 4PT. BEND TEST
TEST # 19456
TEST DATE: 06/25/82 0900
SPEC. NO. 21-4
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=2
MAX. 6420. 2.441
MIN. -7.319 -244.1
CHAN # 43
RUN # 2
LOAD(LBS.)
0
-100
-200
-300
0
2000
4000
6000
8000
10000
STRAIN
A

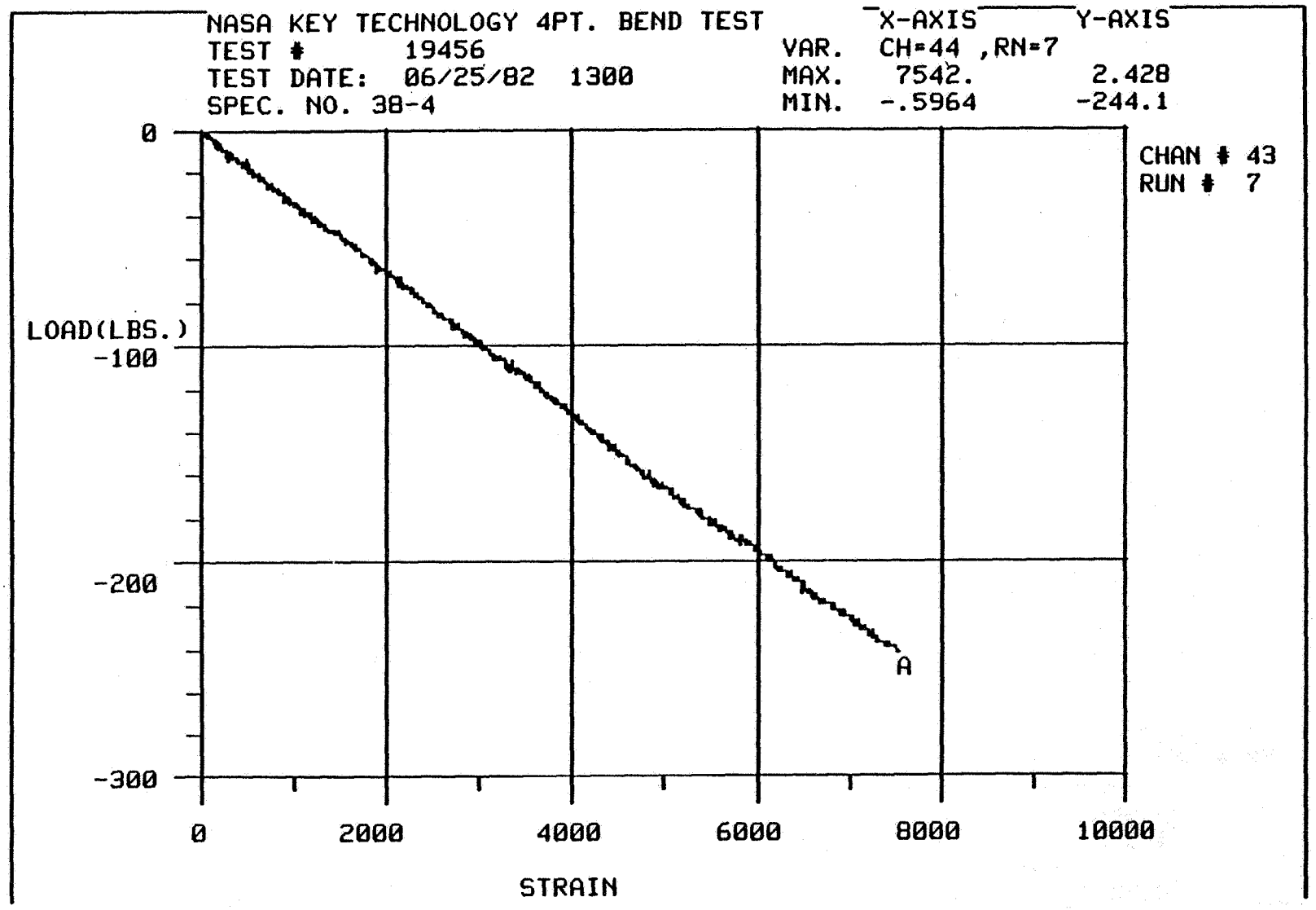

NASA KEY TECHNOLOGY 4PT. BEND TEST
TEST # 19456
TEST DATE: 06/25/82 0947
SPEC. NO. 21-5
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=3
MAX. 6401. -.6186
MIN. 1.224 -244.1
CHAN # 43
RUN # 3
LOAD(LBS.)
0
-100
-200
-300
0
2000
4000
6000
8000
10000
STRAIN
A

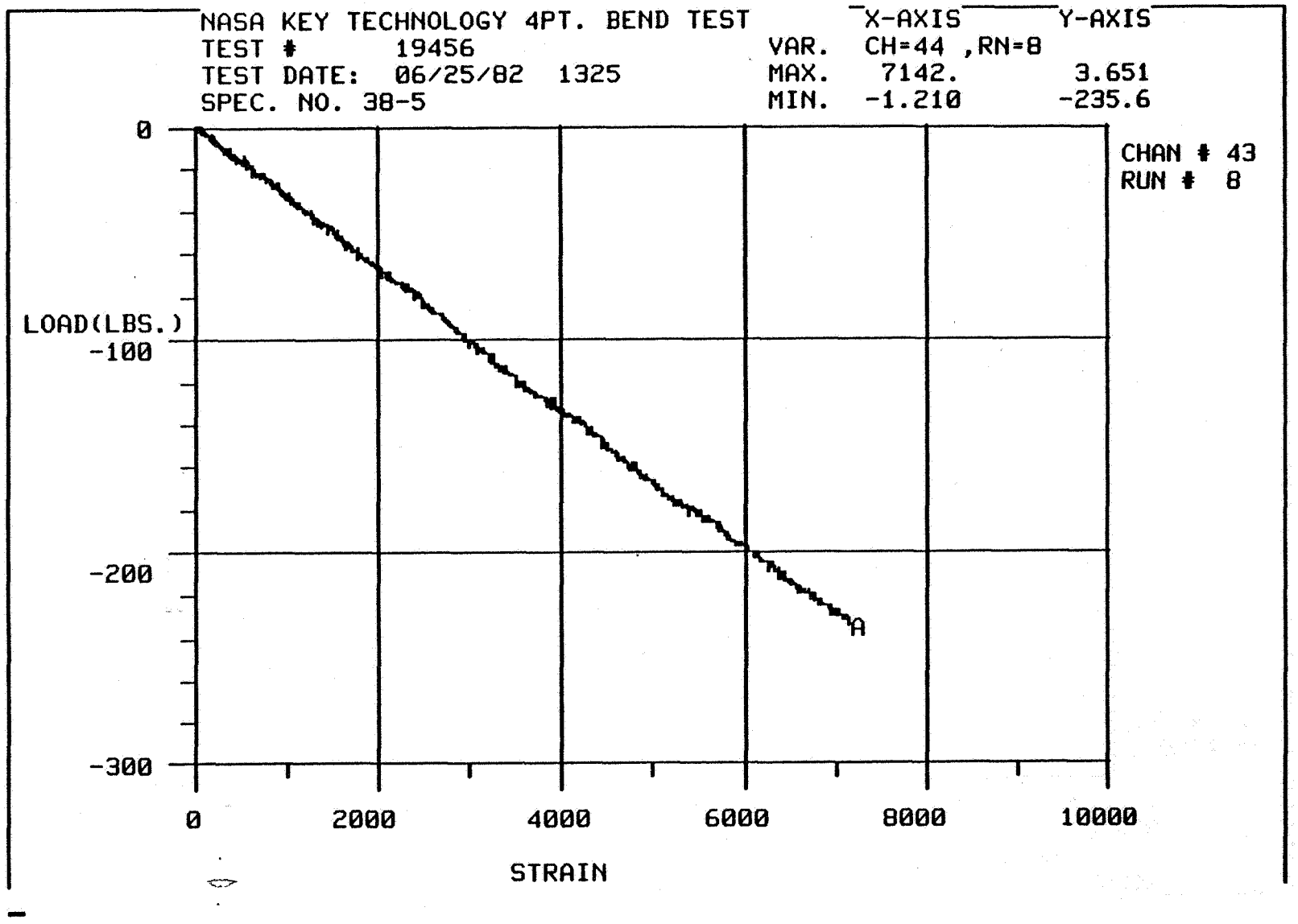

NASA KEY TECHNOLOGY 4 PT. BEND TEST
TEST # 19602
TEST DATE: 07/14/82 1017
SPECIMEN 21-6
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=2
MAX. 7698. -.3065
MIN. -5.493 -277.1
CHAN # 43
RUN # 2
0
-100
-200
-300
-400
-500
LOAD(LBS.)
A
0
2000
4000
6000
8000
10000
STRAIN


NASA KEY TECHNOLOGY 4PT. BEND TEST
TEST # 19456
TEST DATE: 06/25/82 1019
SPEC. NO. 38-1
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=4
MAX. 6721. 2.428
MIN. -2.419 -222.2
CHAN # 43
RUN # 4
LOAD(LBS.)
0
-100
-200
-300
0
2000
4000
6000
8000
10000
STRAIN
A


NASA KEY TECHNOLOGY 4PT. BEND TEST
TEST # 19456
TEST DATE: 06/25/82 1107
SPEC. NO. 38-2
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=5
MAX. 7079. 1.218
MIN. -4.281 -224.6
CHAN # 43
RUN # 5
LOAD(LBS.)
0
-100
-200
-300
0
2000
4000
6000
8000
10000
STRAIN
A


NASA KEY TECHNOLOGY 4PT. BEND TEST
TEST # 19456
TEST DATE: 06/25/82 1244
SPEC. NO.38-3
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=6
MAX. 7816. 4.281
MIN. -2.433 -246.6
CHAN # 43
RUN # 6
LOAD(LBS.)
0
-100
-200
-300
0
2000
4000
6000
8000
10000
STRAIN
A


NASA KEY TECHNOLOGY 4PT. BEND TEST
TEST # 19456
TEST DATE: 06/25/82 1300
SPEC. NO. 38-4
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=7
MAX. 7542. 2.428
MIN. -.5964 -244.1
CHAN # 43
RUN # 7
LOAD(LBS.)
0
-100
-200
-300
0
2000
4000
6000
8000
10000
STRAIN
A


NASA KEY TECHNOLOGY 4PT. BEND TEST
TEST # 19456
TEST DATE: 06/25/82 1325
SPEC. NO. 38-5
X-AXIS
Y-AXIS
VAR. CH=44 ,RN=8
MAX. 7142. 3.651
MIN. -1.210 -235.6
CHAN # 43
RUN # 8
0
LOAD(LBS.)
-100
-200
-300
0
2000
4000
6000
8000
10000
STRAIN
A

APPENDIX B7

P. SANDIFER
C. LOOPER

DATE 6/29/82

LOCKHEED-CALIFORNIA COMPANY
A DIVISION OF LOCKHEED CORPORATION
ENGINEERS NOTEBOOK

Nº 11223-49

SUBJECT ST-5 DOUBLE CANTILEVER BEAM TEST

REF

WO
EWA

COUPON #21-2 FRONT	CRACK LENGTH READING ①	②	③	④	⑤
MAX LOAD /LB	123	126	110	100	
MIN LOAD /LB	94	85	88	48	
CRACK LGTH /IN	.389	1.351	1.991	3.759	
WAIT TIME /MIN	15	10	10	14	
REAR					
CRACK LGTH /IN	.427	1.428	2.061	3.794	
WAIT TIME /MIN	12	14	14	19	
COUPON #21-3 FRONT.					
MAX LOAD /LB	145	92	88	71	57
MIN LOAD /LB	60	68	56	48	41
WAIT TIME /MIN	18	12	15	12	16
CRACK LGTH /IN	.718	1.278	2.377	3.333	4.072
REAR.					
CRACK LGTH /IN	.852	1.377	2.403	3.435	4.203
WAIT TIME /MIN	12	16	13	17	10
COUPON #21-4 FRONT					
MAX LOAD /LBS	108	113	48	73	61
MIN LOAD /LBS	84	63	59	50	44
CRACK LGTH /IN	.084	.773	1.289	1.906	2.638
WAIT TIME /MIN	16	9	14	15	11
REAR					
CRACK LGTH /IN	.085	.769	1.311	1.852	2.688
WAIT TIME /MIN	20	12	16	12	14

NOTE: WAIT TIME IS FROM THE MOMENT THE TEST MACHINE STOPS LOADING UNTIL THE CRACK LENGTH IS MEASURED

CONTINUED ON

P. SANDIFER	DATE 6/	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11223-41
FROM LOOPER	/29/	SUBJECT ST-5 DOUBLE	REF
MODEL	/82	CONTILEVER BEAM TEST	W.O. EWA

CONTINUED FROM E N

COUPON #21-5 FRONT	CRACK LENGTH READING ①	②	③	④	⑤
MAX LOAD /LB	120	118	91	74	63
MIN LOAD /LB	80	72	64	56	42
CRACK LGTH /IN	.269	.869	1.346	2.015	2.655
WAIT TIME /MIN	15	11	13	11	17
REAR					
CRACK LGTH /IN	.220	.881	1.438	2.023	2.670
WAIT TIME /MIN	12	13	11	15	13
COUPON #21-8 FRONT.					
MAX. LOAD /LB	162	79	68		
MIN. LOAD /LB	60	58	50		
CRACK LGTH /IN	.97	1.386	2.381		
WAIT TIME /MIN	30	10	7		
REAR					
CRACK LGTH /IN	.883	1.539	2.359		
WAIT TIME /MIN	19	22	5		

CONTINUED ON F N

TO P. SANDIFER	DATE 6/	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11223-42
FROM C. LOOPER	/29/	SUBJECT ST-5 DOUBLE	REF
MODEL	/82	CANTILEVER BEAM TEST	W.O. / EWA

CONTINUED FROM E.N. #

COUPON #38-1 FRONT	CRACK LENGTH READING ①	②	③	④	⑤
MAX. LOAD /LB	185	142	114	96	76
MIN LOAD /LB	120	96	80	68	60
CRACK LGTH /IN	.320	.892	1.510	2.288	2.828
WAIT TIME /MIN	12	12	11	13	10
REAR					
CRACK LGTH /IN	.304	.847	1.514	2.254	2.924
WAIT TIME /MIN	15	9	13	10	12
COUPON #38-2 FRONT					
MAX LOAD/LB	180	143	127	95	84
MIN LOAD /LB	106	100	80	72	56
CRACK LGTH /IN	.446	.929	1.834	2.481	3.554
WAIT TIME/MIN	14	11	18	25	13
REAR					
CRACK LGTH/IN	.397	.707	1.341 *	2.199	3.304
WAIT TIME /MIN	11	16	16	22	17
COUPON #38-3 FRONT					
MAX LOAD /LB	195	90	82		
MIN LOAD /LB	60	68	27		
CRACK LGTH /IN	1.106	2.060	3.925		
WAIT TIME/MIN	16	10	16		
REAR					
CRACK LGTH /IN	1.135	2.015	3.935		
WAIT TIME /MIN	12	12	12		

*DEBOND BETWEEN GRAPHITE AND ALUM BEAM

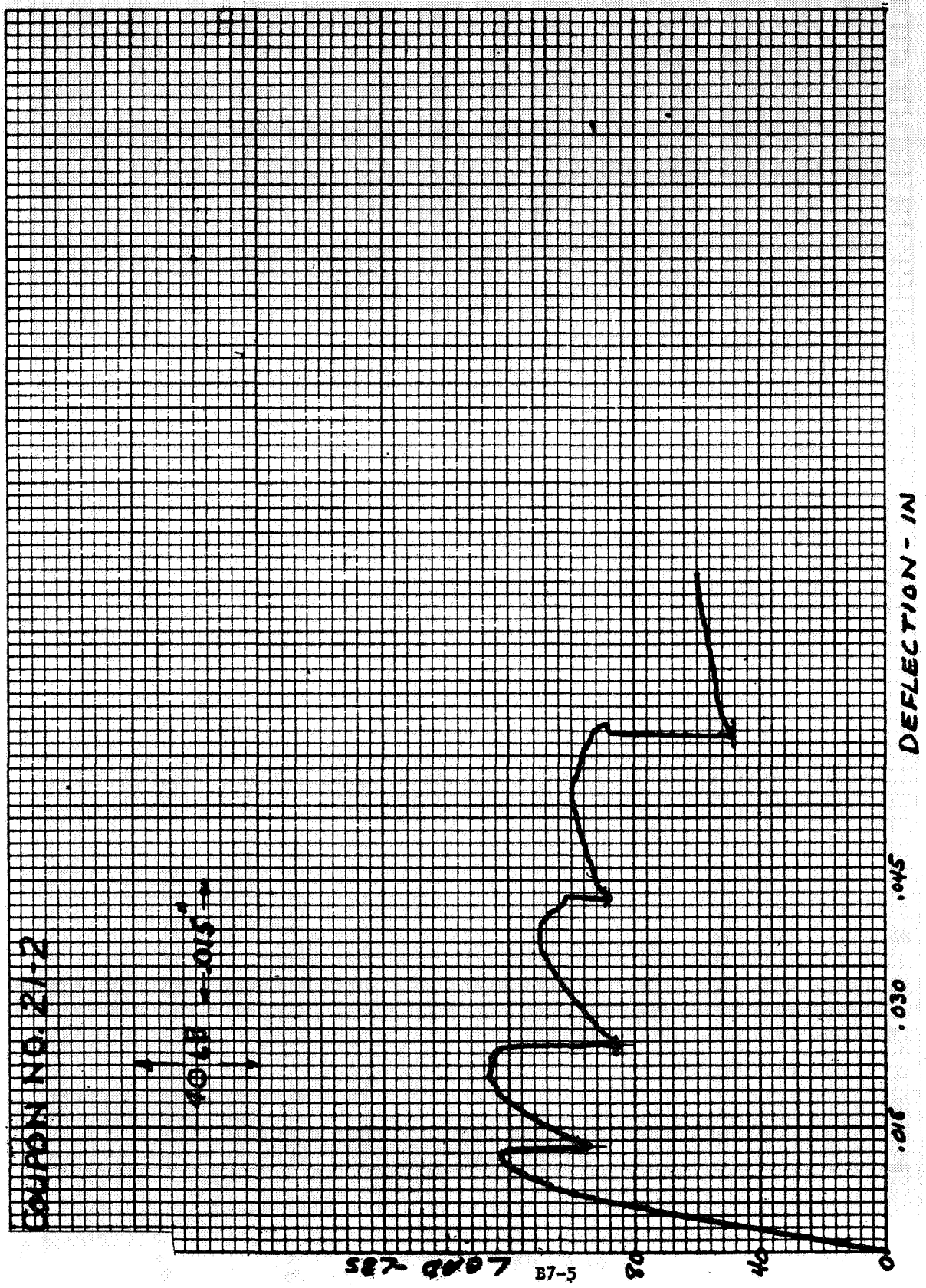
TO P. SANDIFER	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11223-43
FROM O. LOOPER		SUBJECT ST-5 DOUBLE CANTILEVER BEAM TEST	REF
MODEL			W.O. EWA

CONTINUED FROM E.N. # ...

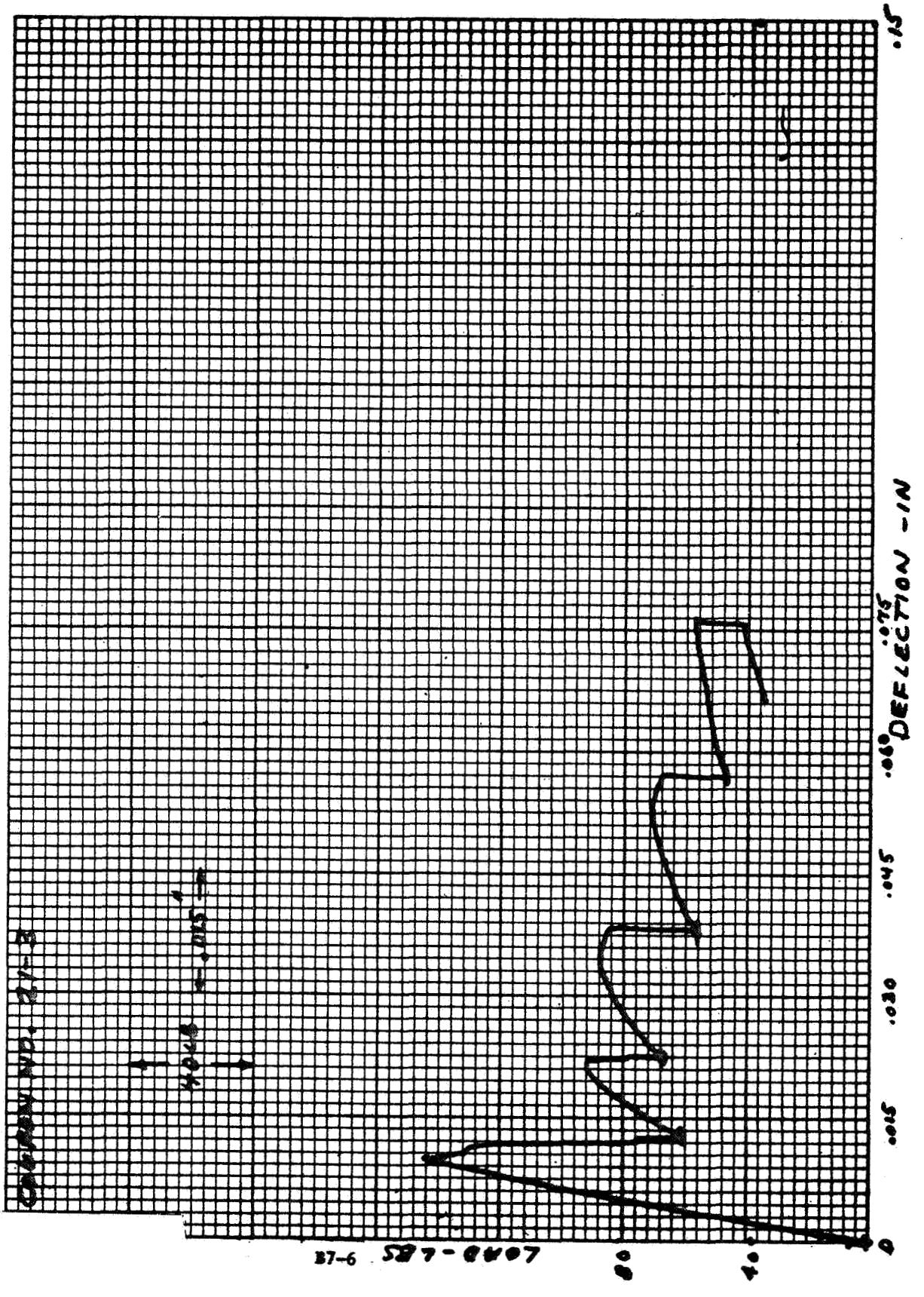
COUPON NO 38-4 FRONT	CRACK LENGTH READING ①	②	③	④	⑤
MAX LOAD /LB	200	83			
MIN LOAD / LB	56	32			
CRACK LGTH /IN	1.291	3.273			
WAIT TIME /MIN	13	12			
REAR					
CRACK LGTH /IN	1.297	3.280			
WAIT TIME / MIN	~16	10			
COUPON #38-5					
MAX LOAD / LB	164	161	83	88	
MIN LOAD / LB	128	59	68	40	
CRACK LGTH /IN	.893	1.361	1.641	2.778	
WAIT TIME / MIN	12	20	12	18	
REAR					
CRACK LGTH /IN	.224	1.315	1.629	2.681	
WAIT TIME / MIN	14	18	15	16	

CONTINUED ON E.N. #

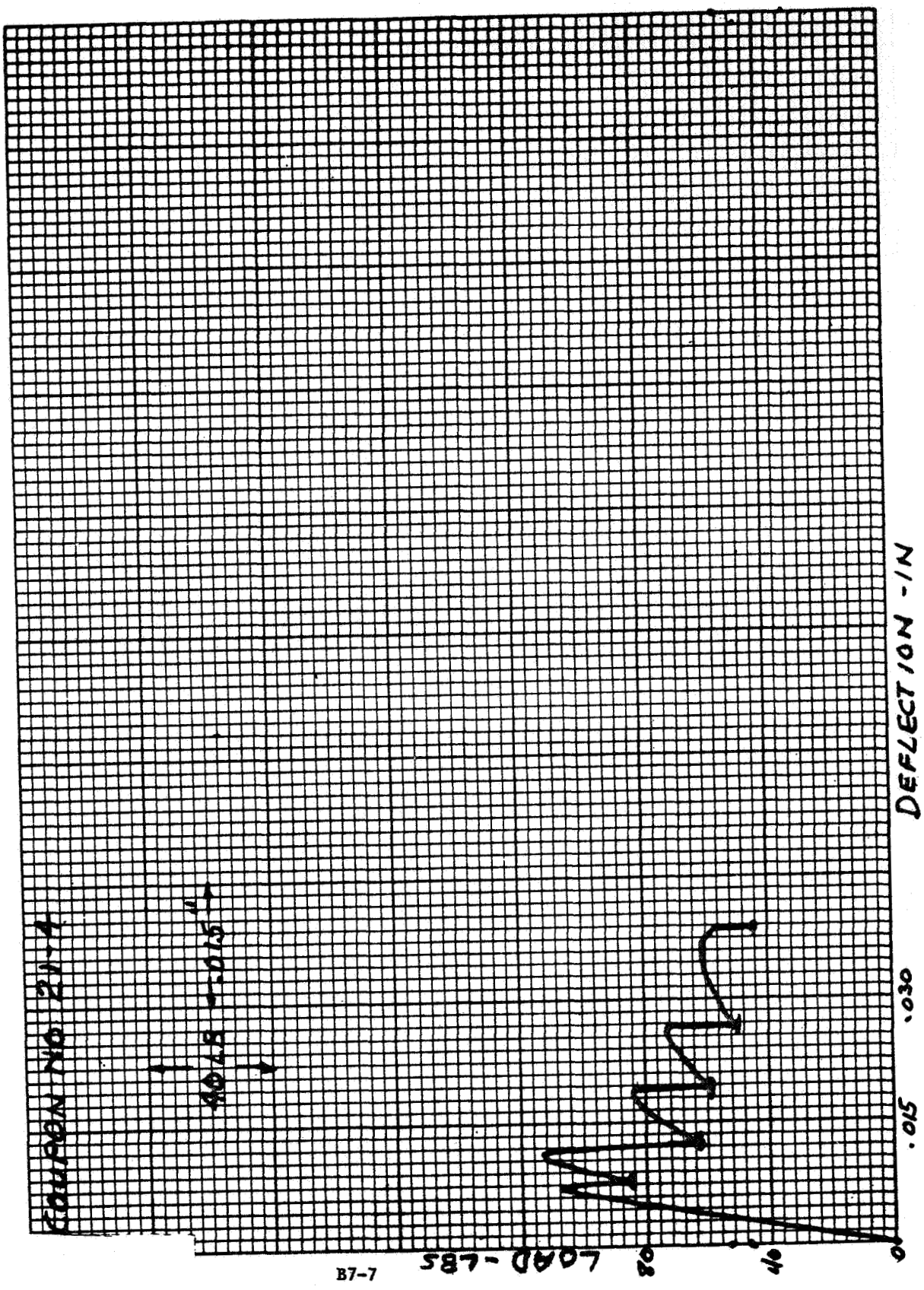
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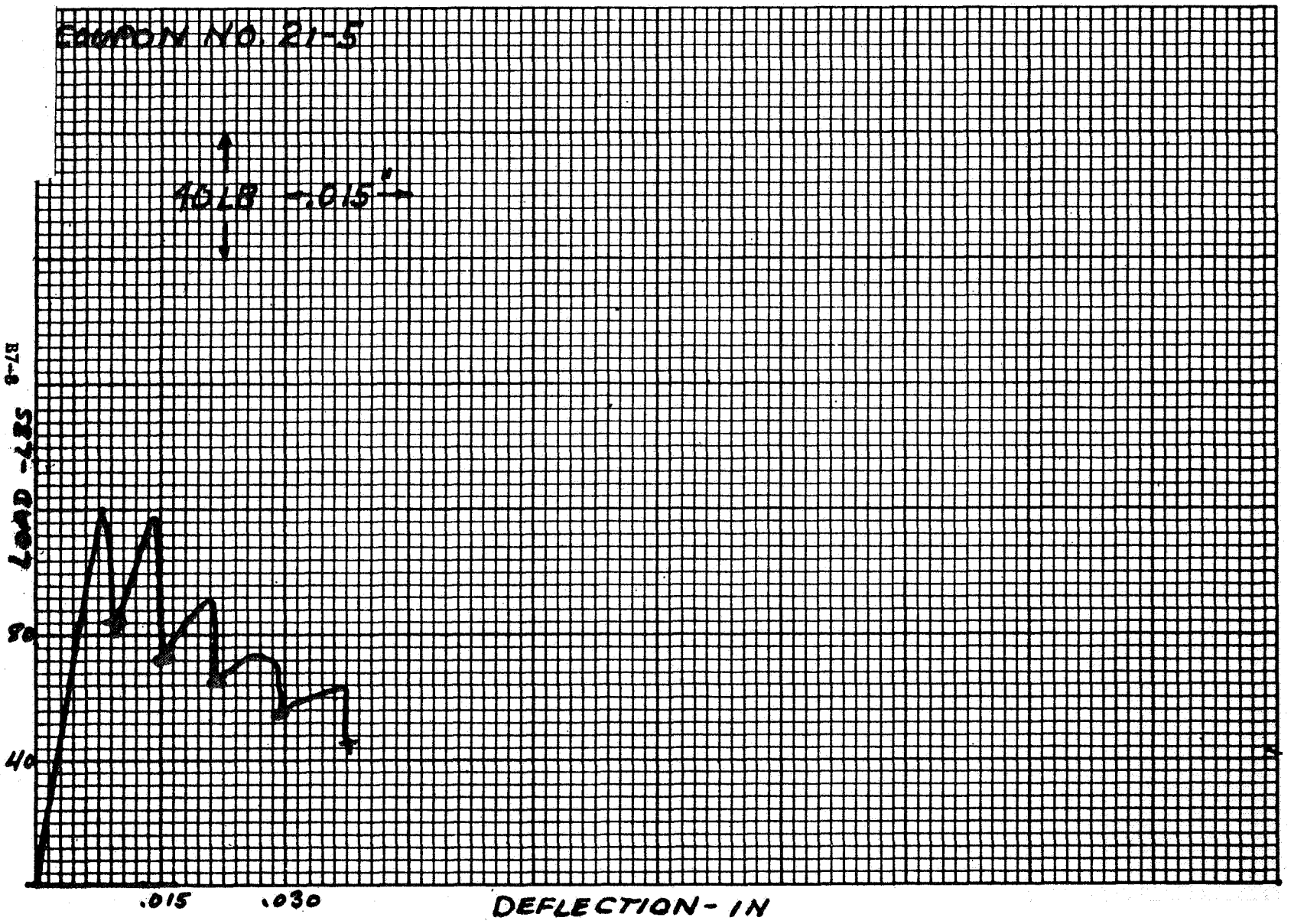


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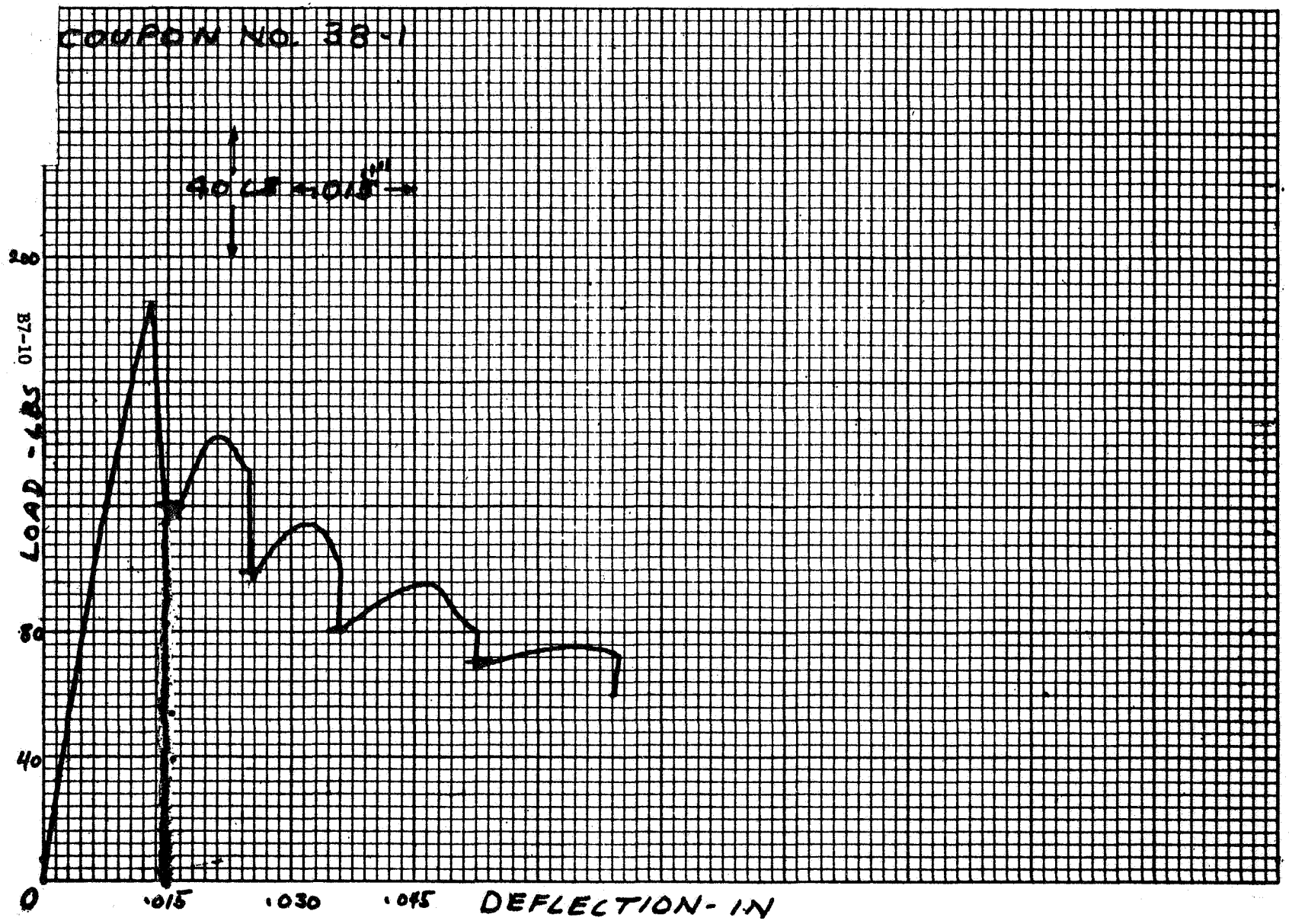


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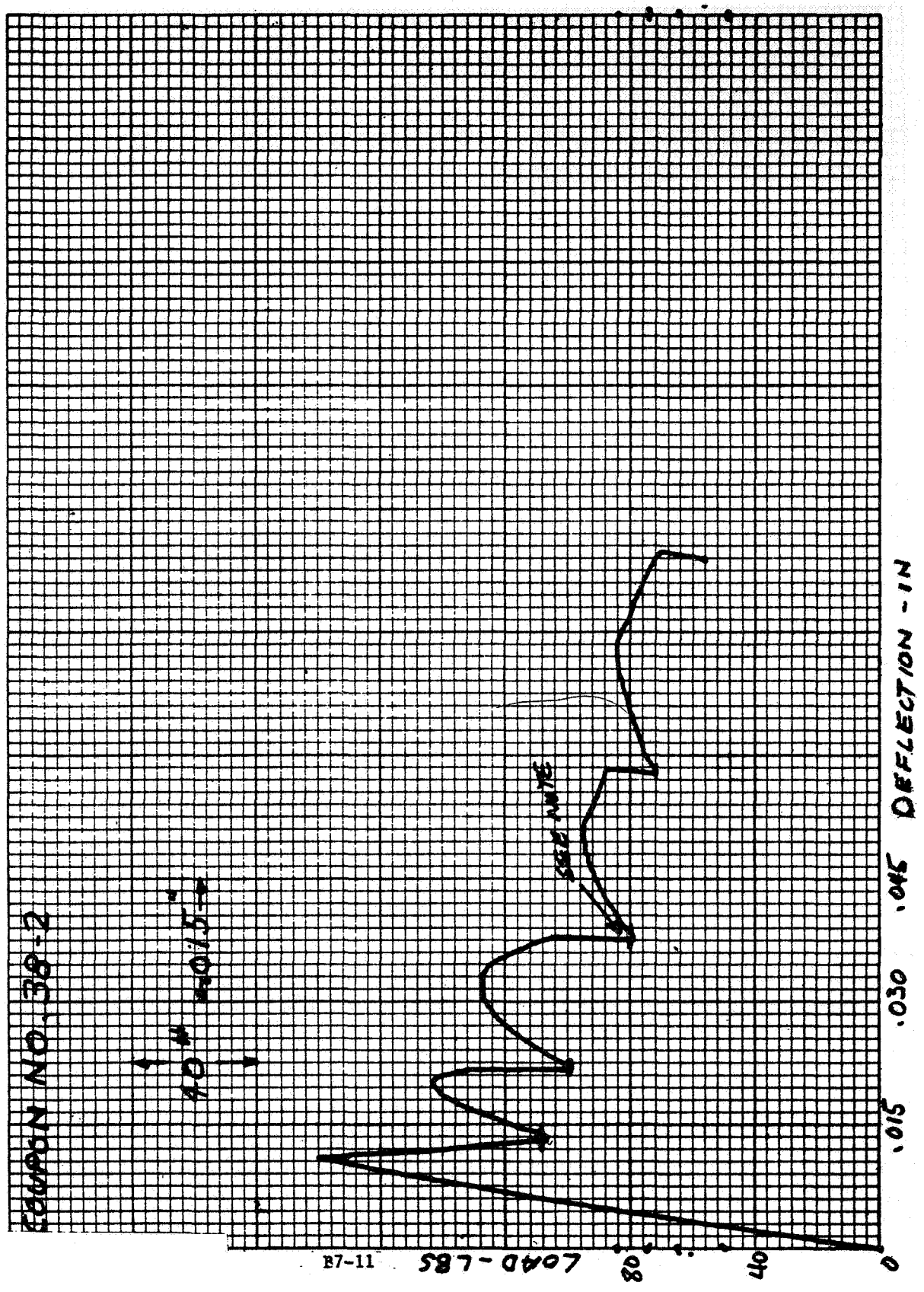


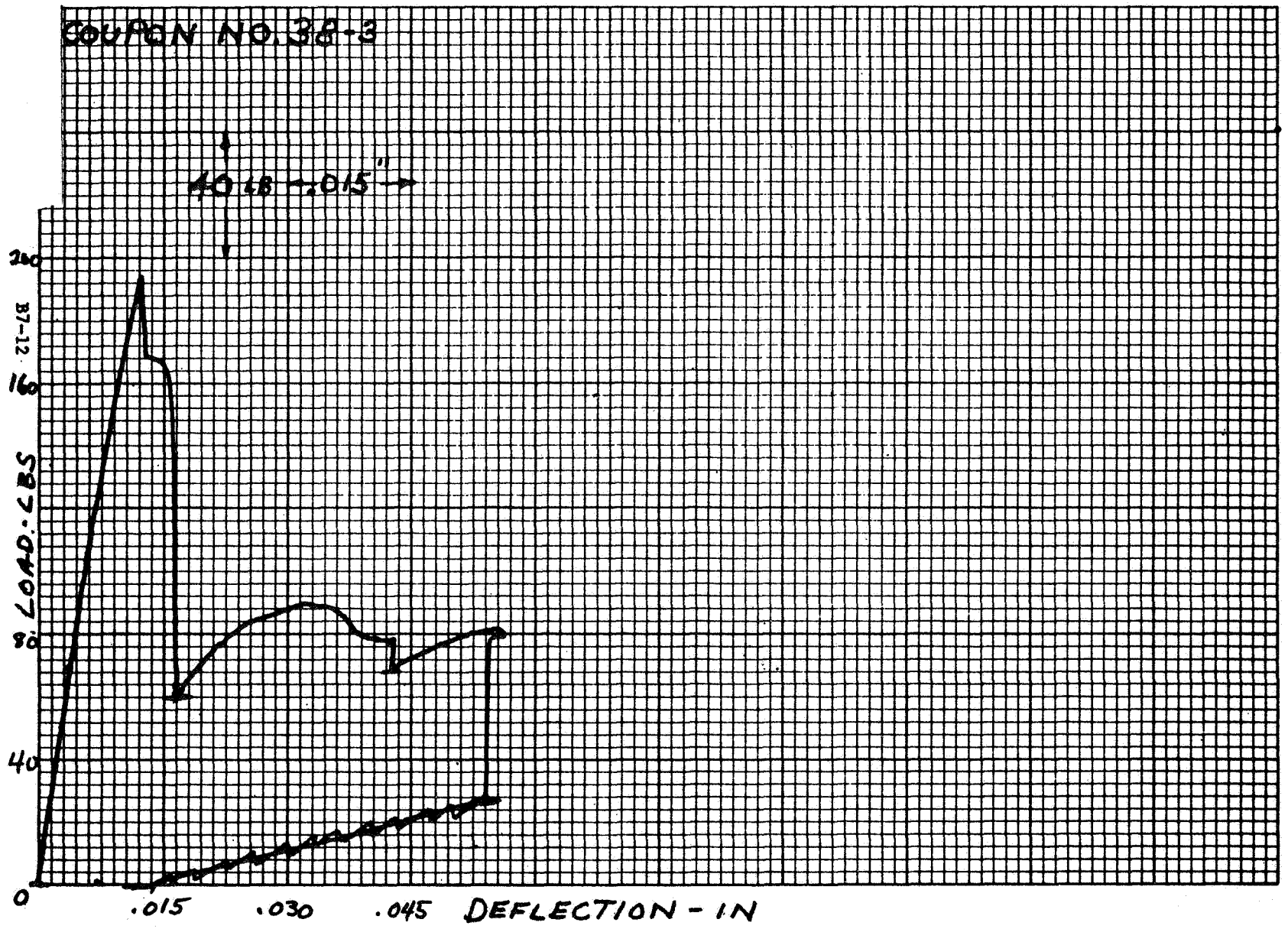

EMMON NO. 21-5
40 LB
.015"
LOAD - LBS
80
40
.015
.030
DEFLECTION - IN

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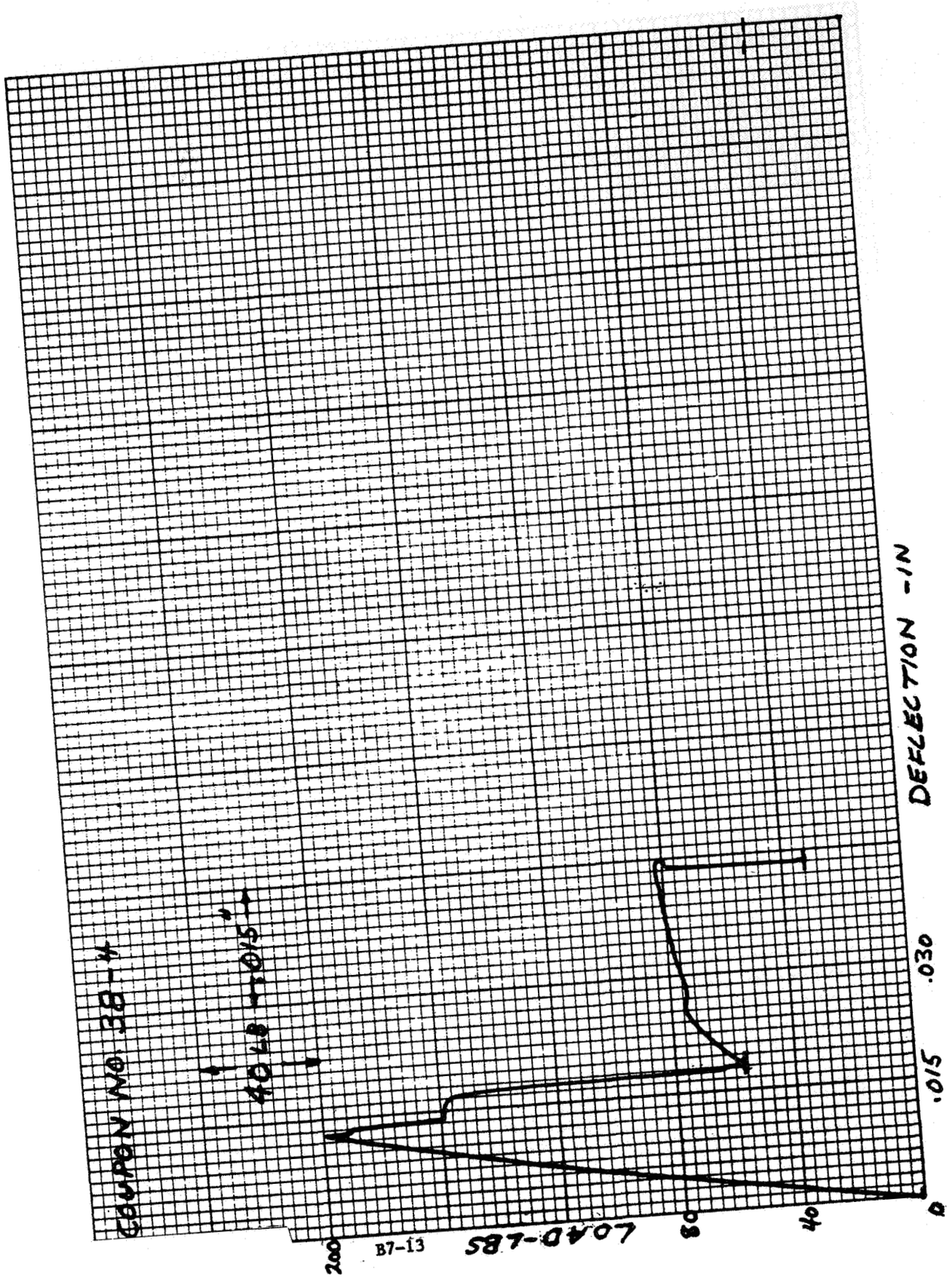

COUPON NO. 38-1
40 CM = .015 IN
LOAD - LBS
87-10
80
40
0
.015
.030
.045
DEFLECTION - IN

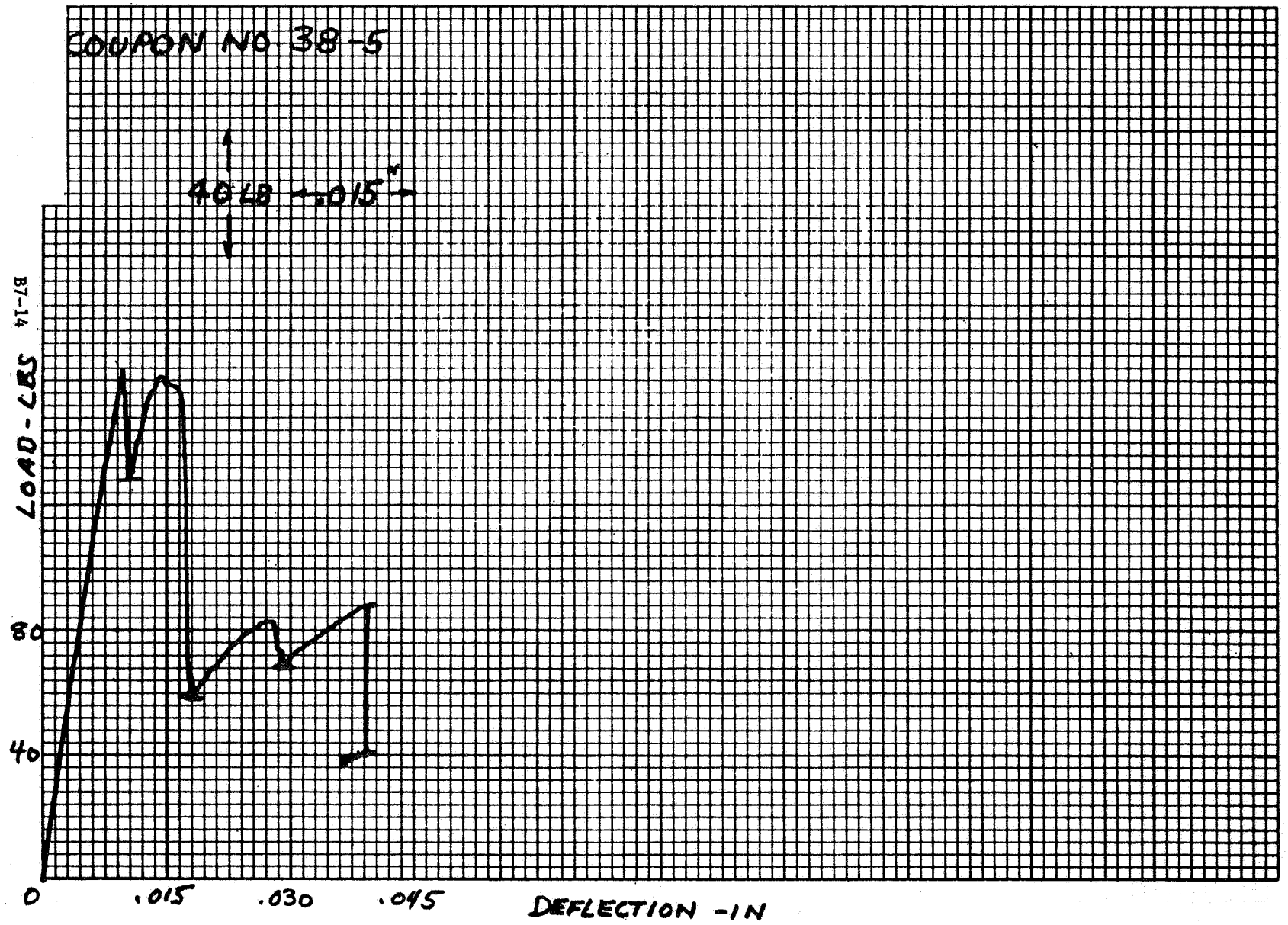
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COUPON NO. 38-3
40 LB → .015" →
B7-12
LOAD - LBS
200
160
80
40
0
.015
.030
.045
DEFLECTION - IN

ORIGINAL PAGE IS
OF POOR QUALITY




COUPON NO 38-5
40 LB
.015"
LOAD - LBS
B7-14
80
40
0
.015
.030
.045
DEFLECTION - IN

APPENDIX B8

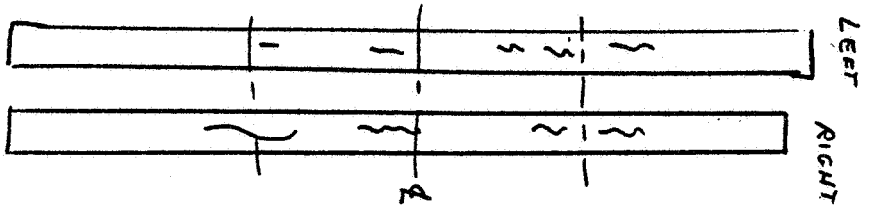
P. SANDIFER	DATE 6	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11223-22
C. LOOPER	14 82	SUBJECT ST-2 DELAM STUDY	REF
			WO FWA

CONTINUED FROM E.N. 11223-20

COUPON NO 40-5, DELAM FULL LGTH RIGHT SIDE
MAX LOAD AT FAILURE 5811 LBS
TOTAL DEFLECTION.
DATA CENTRAL TEST NO. 19285 RUN NO. 1

6-15-82

COUPON NO. 19-12. DELAM NOTED BELOW
MAX LOAD 2855 LBS.
TOTAL DEFL.
DATA CENTRAL TEST NO 19290, RUN NO 1



COUPON NO. 19-1, NOTED DELAM. @ APPROX. 2300 LB.
CONTINUED TO LOAD UNTIL DELAM. FULL LENGTH BOTH SIDES
MAX. LOAD. 3028 LBS,
TOTAL DEFL.
DATA CENTRAL TEST. NO. 19300 RUN NO. 1

COUPON NO. 19-2, NOTICED DELAM @ APPROX. 2200 LBS. CONTINUED UNTIL DELAM FULL LENGTH RIGHT SIDE AND ALMOST FULL LENGTH LEFT SIDE
MAX LOAD 2697 LB.
TOTAL DEFL.
DATA CENTRAL TEST NO. 19303 RUN. NO 1

CONTINUED IN E.N. #

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OF POOR QUALITY

	DATE	LOCKHEED-CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11223-20
P. SANDIFER	6/10/82	SUBJECT ST-2 DELAM. STUDY	REF
FROM G. LOOPER			AD LMA
MODEL			

COMPANION TEST 11223-18

COUPON NO. 20-4, DELAM NOTED UPPER HALF LEFT SIDE
TOTAL DEFT.
MAX. LOAD 2865 LBS
DATA CENTRAL TEST NO. 19259 RUN NO. 1
RUN TO FAILURE - DC TEST NO. 19260 RUN NO 1
MAX LOAD 5839 LBS
TOTAL DEFL.

COUPON NO. 40-1 DELAM TOP TO BOTT RIGHT SIDE
TOTAL DEFL.
MAX LOAD 3506 LBS
DATA CENTRAL TEST NO. 19262 RUN 1

6-14-82
COUPON NO 40-2 DELAM. FULL LGTH LEFT SIDE

TOTAL DEFL.
MAX LOAD 3493 LBS
DATA CENTRAL TEST NO. 19278 RUN NO. 1

COUPON NO. 40-3 DELAM ± 1.5 INCH ABOUT LOWER KNIFE EDGE POINT LEFT SIDE-
MAX LOAD 3159 LBS
TOTAL DEFL.
DATA CENTRAL TEST NO. 19280 RUN # 1

COUPON 40-4 DELAM FULL LGTH. RIGHT SIDE
MAX LOAD AT FAILURE 6109 LBS
TOTAL DEFL-
DATA CENTRAL TEST NO. 19282 RUN NO 1

CONTINUED ON PAGE #

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P. SANDIFER	PAGE 6	LOCKHEED CALIFORNIA COMPANY A DIVISION OF LOCKHEED CORPORATION ENGINEERS NOTEBOOK	Nº 11223-18
G. LOOPER	9	SUBJECT	REF
	82	ST-2, DELAM.	A/C GWA

GRIP PRESS 1000 LB
LOAD RATE - .002 mm/SEC = .00008"/SEC. WHICH IS GIVES A SETTING OF 6.2×10^{3}

COUPON NO. 20-11. RAN TO FAILURE
LOUD SNAP AT APPROX. 2770 LBS. LOAD
THE FULL LENGTH OF BOTH SIDE WERE
DELAMINATED.
TOTAL DEFL. WAS .044 INCH.
FAILURE LOAD _
DATA CENTRAL TEST NO. 19241, RUN NO. 1

COUPON NO. 20-1, RAN TO DELAMINATION
NOTED. - LOWER RIGHT HAND SIDE
TOTAL DEFL. WAS.
MAX. LOAD 3256 LBS
DATA CENTRAL TEST NO. 19249, RUN NO. 3.

COUPON NO. 20-2, DELAMINATION NOTED FULL
LENGTH LEFT SIDE.
TOTAL DEFL. WAS
MAX LOAD 3257 LBS
DATA CENTRAL TEST NO. 19256 RUN. NO. 1

COUPON NO. 20-3, DELAM NOTED ABOUT CENTER
LINE ±1.5 INCH.
TOTAL DEFL.
MAX LOAD ~~3225 LBS~~ 3129 LBS
DATA CENTRAL TEST NO. 19256 RUN NO. 4

11223-20

P. SANDIFER 6
C. LOOPER 16

LOCKHEED-CALIFORNIA COMPANY
ENGINEERS NOTEBOOK

Nº 11223-24

82 ST-2 DELAM. STUDY

COUPON NO. 39-3, DELAM. FROM UPPER GRIP TO MID. POINT BETWEEN UPPER 2" MARK AND ℄ RIGHT SIDE — LEFT SIDE FROM ℄ DOWN ABOUT 1.2"
MAX. LOAD 3236 LB
TOTAL DEFL.
DATA CENTRAL TEST NO. 19337, RUN NO. 1

COUPON NO. 39-4, DELAM RIGHT SIDE 1" LONG MIDWAY BETWEEN ℄ AND LOWER 2" MARK
MAX LOAD 2839 LB
TOTAL DEFL.
DATA CENTRAL TEST NO. 19338, RUN NO. 1

COUPON NO. 39-5, DELAM. LEFT SIDE 1" LONG GOING UP FROM UPPER 2" MARK
MAX. LOAD 3290 LB
TOTAL DEFL.
DATA CENTRAL TEST NO. 19339, RUN NO. 1

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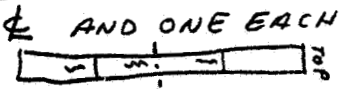
P. SANDIFER
C. LOOPER
6/15/82
ST-2 DELAM STUDY

COUPON NO. 19-3, NOTED DELAM AT APPROX. 2130 LBS. CONTINUED UNTIL DELAM. FULL LENGTH LEFT SIDE ALSO ALMOST FULL LENGTH RIGHT SIDE
MAX LOAD 2760 LBS
TOTAL. DEFL.
DATA CENTRAL TEST NO. 19313 RUN NO. 1

COUPON NO. 19-4, NOTED DELAM. CENTER RIGHT & LEFT SIDE
MAX LOAD 2156 LBS
TOTAL DEFL.
DATA CENTRAL TEST NO. 19320 RUN NO. 2

6-16-82

COUPON NO 19-5, NOTED DELAM LEFT SIDE IN THREE PLACES EACH BEING ABOUT 1"-1.5" LONG ONE JUST BELOW ℄ AND ONE EACH JUST BELOW THE TWO INCH MARKS



MAX LOAD 2067LB
TOTAL DEFL
DATA CENTRAL TEST NO. 19326, RUN NO. 1

COUPON NO. 39-1, DELAM 1" LONG ABOVE LOWER 2" MARK LEFT SIDE.
MAX LOAD 2902 LBS
TOTAL DEFL.
DATA CENTRAL TEST NO. 19329, RUN NO. 1

COUPON NO. 39-2, DELAM 2/3 UP FROM BOTTOM GRIP LEFT SIDE
MAX LOAD 3218 LB.
TOTAL DEFL.
DATA CENTRAL TEST NO. 19334, RUN NO. 2

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ENGINEERS NOTEBOOK

Nº 11223-17

P. SANDIFER 6/82
C. COOPER

8 PLY LAY UP
MEASUREMENTS

ST-2 DELAM. STUDY

+35/-35/0/90/90/0/-35/+35
MEASUREMENTS

LOCATION	ID 20-11	20-1	20-2	20-3	20-4	40-1	40-2	40-3	40-4	4-5
1	.0400	.0395	.0399	0.0391	.0395	.0432	.0440	.0437	.0444	.0440
2	.0405	.0400	.0402	.0383	.0397	.0433	.0441	.0446	.0445	.0443
3	.0383	.0406	.0386	.0392	.0394	.0426	.0440	.0441	.0449	.0448
4	.0393	.0417	.0384	.0398	.0387	.0434	.0430	.0443	.0437	.0437
5	.0400	.0400	.0388	.0379	.0382	.0441	.0450	.0445	.0443	.0445
6	.0400	.0404	.0378	.0397	.0385	.0441	.0443	.0448	.0450	.0446
AVE	.0397	.0404	.0389	.0390	.0386	.0434	.0441	.0443	.0445	.0443
7	1.5066	1.5068	1.5008	1.5061	1.5060	1.4975	1.4979	1.4974	1.4973	1.4960
8	1.5060	1.5060	1.5027	1.5063	1.5060	1.4972	1.4960	1.4974	1.4977	1.4962
9	1.5063	1.5050	1.5039	1.5059	1.5060	1.4977	1.4973	1.4975	1.4963	1.4968
AVE	1.5063	1.5060	1.5025	1.5057	1.5060	1.4975	1.4971	1.4974	1.4973	1.4963
AREA	.0598	.0608	0.0584	0.0587	0.0580	.0650	.0660	.0663	.0666	.0663

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P. SANDIFER
C. COOPER

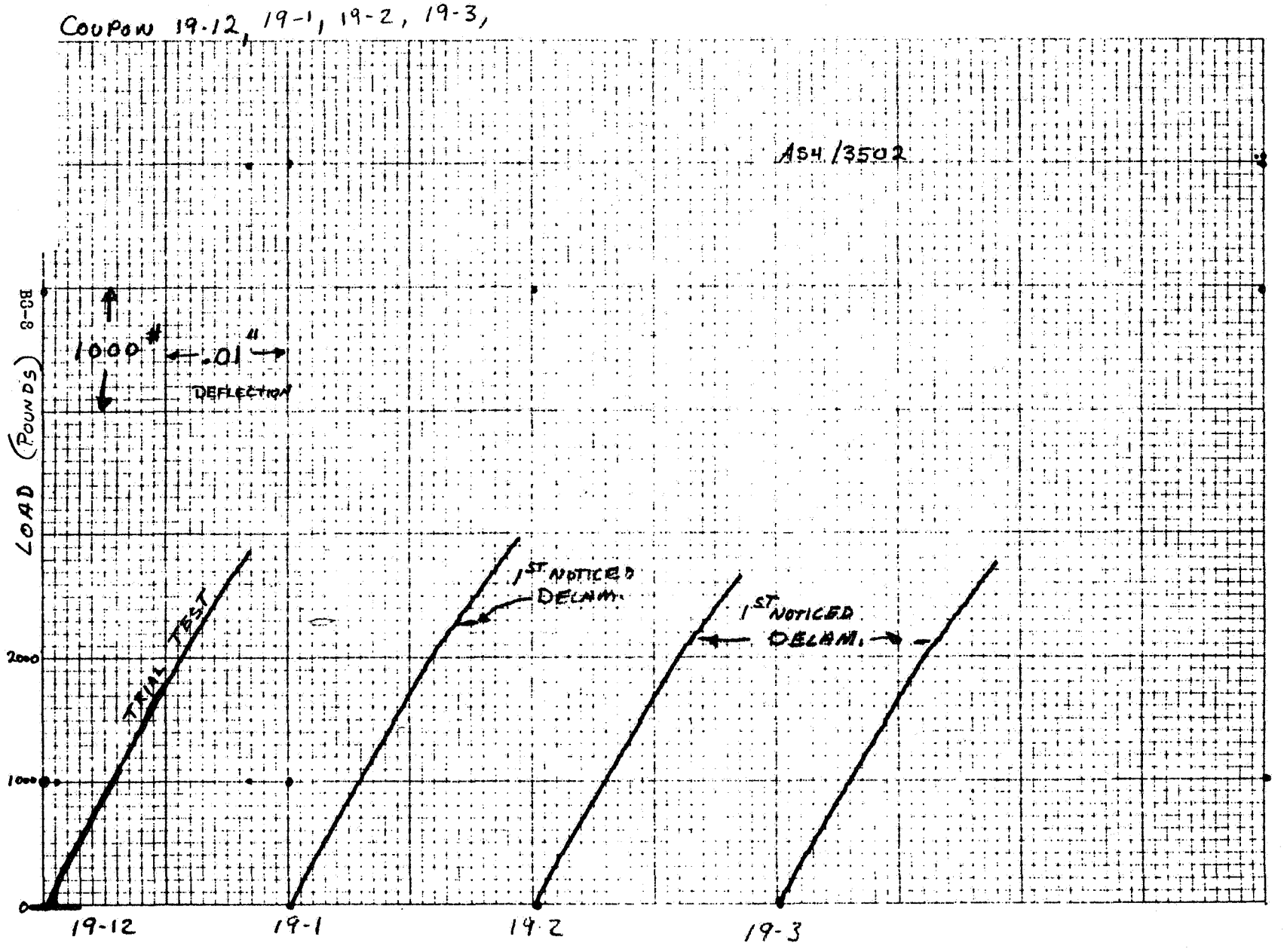
6/82

ENGINEERS NOTEBOOK

Nº 11223-19

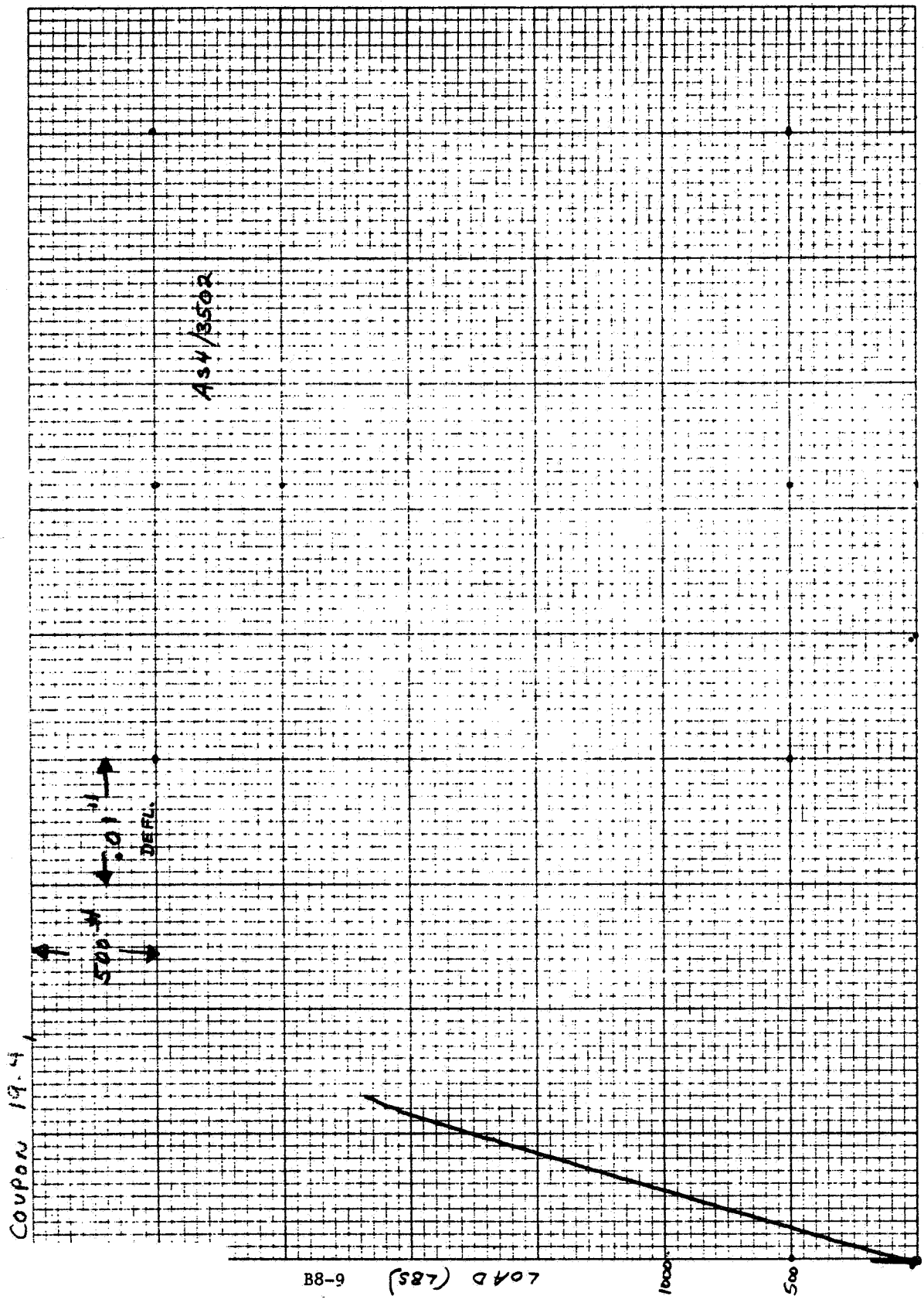
ST-2, DELAM STUDY

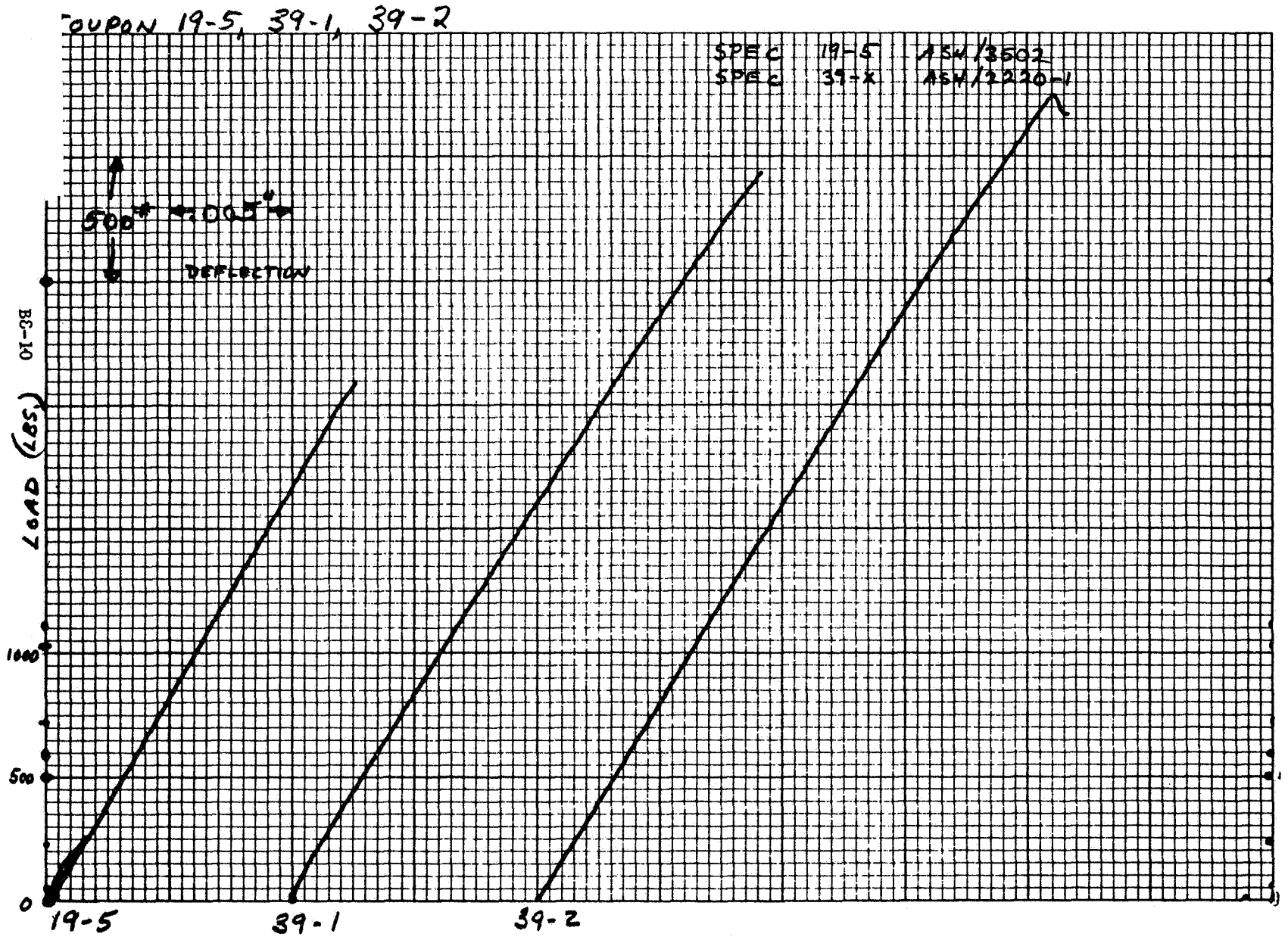
LOCATION	I.D. 19-1	19-2	19-3	19-4	19-5	39-1	39-2	39-3	39-4	39-5	19-12
1	0.0531	0.0589	0.0537	0.0552	0.0542	0.0568	0.0574	0.0587	0.0580	0.0589	.0553
2	0.0542	0.0543	0.0549	0.0557	0.0543	0.0592	0.0576	0.0599	0.0585	0.0592	.0554
3	0.0547	0.0538	0.0543	0.0542	0.0529	0.0588	0.0588	0.0582	0.0590	0.0579	.0547
4	0.0528	0.0528	0.0542	0.0537	0.0542	0.0573	0.0582	0.0592	0.0569	0.0587	.0555
5	0.0543	0.0537	0.0531	0.0548	0.0548	0.0576	0.0596	0.0594	0.0596	0.0588	.0544
6	0.0526	0.0547	0.0534	0.0555	0.0530	0.0592	0.0594	0.0587	0.0599	0.0592	.0555
AVERAGE	0.0536	0.0547	0.0539	0.0548	0.0539	0.0581	0.0582	0.0588	0.0583	0.0588	.0551
7	1.5105	1.5105	1.5106	1.5103	1.5102	1.5034	1.5036	1.5032	1.5035	1.5023	1.5004
8	1.5111	1.5103	1.5107	1.5103	1.5099	1.5041	1.5029	1.5019	1.5039	1.5032	1.4995
9	1.5104	1.5107	1.5105	1.5102	1.5090	1.5039	1.5039	1.5007	1.5043	1.5038	1.4993
AVERAGE	1.5105	1.5105	1.5106	1.5103	1.5097	1.5038	1.5038	1.5019	1.5039	1.5033	1.499
AREA	0.0810	0.0811	0.0814	0.0829	0.0814	0.0874	0.0875	0.0883	0.0877	0.0884	.0826



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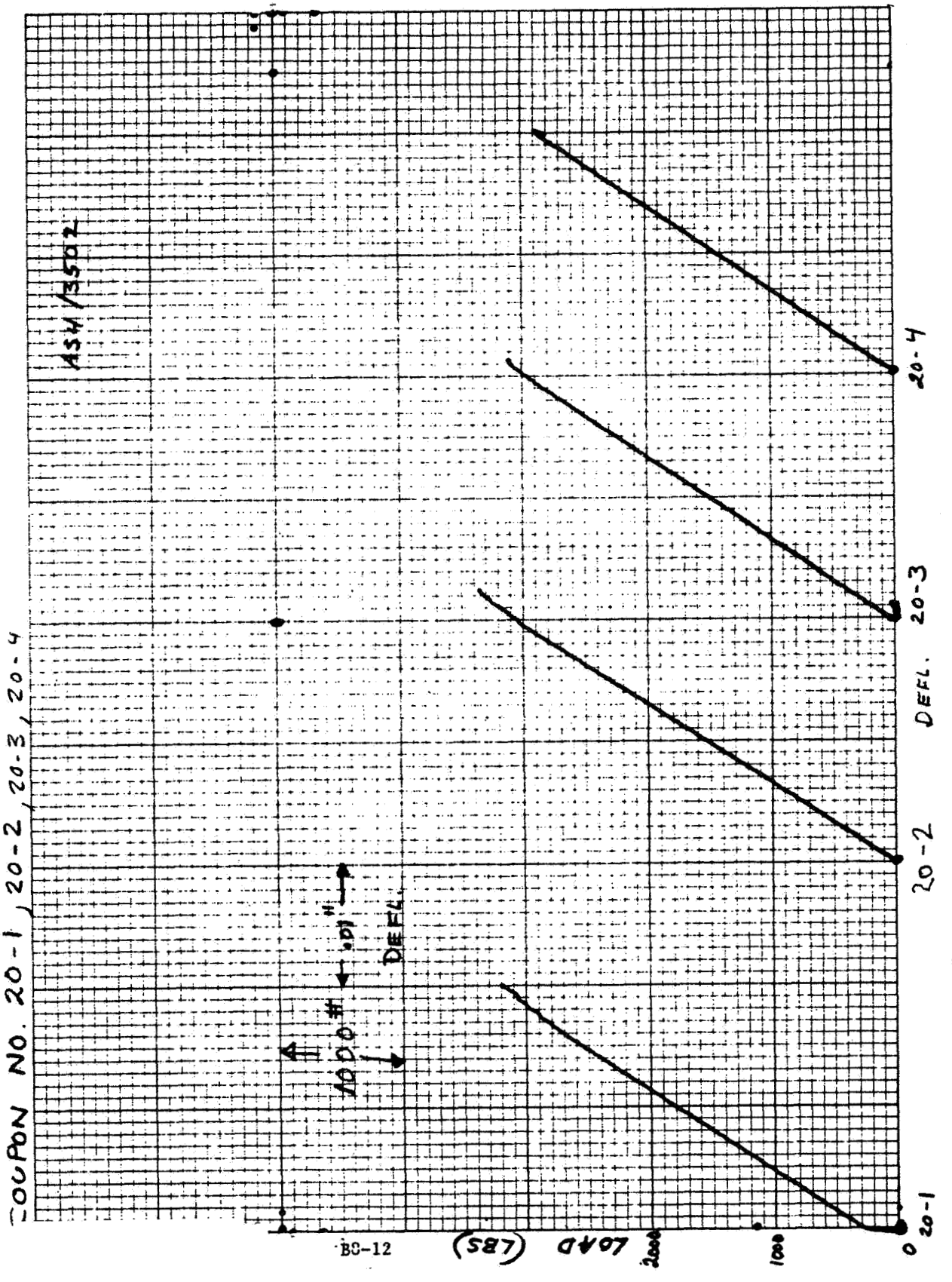
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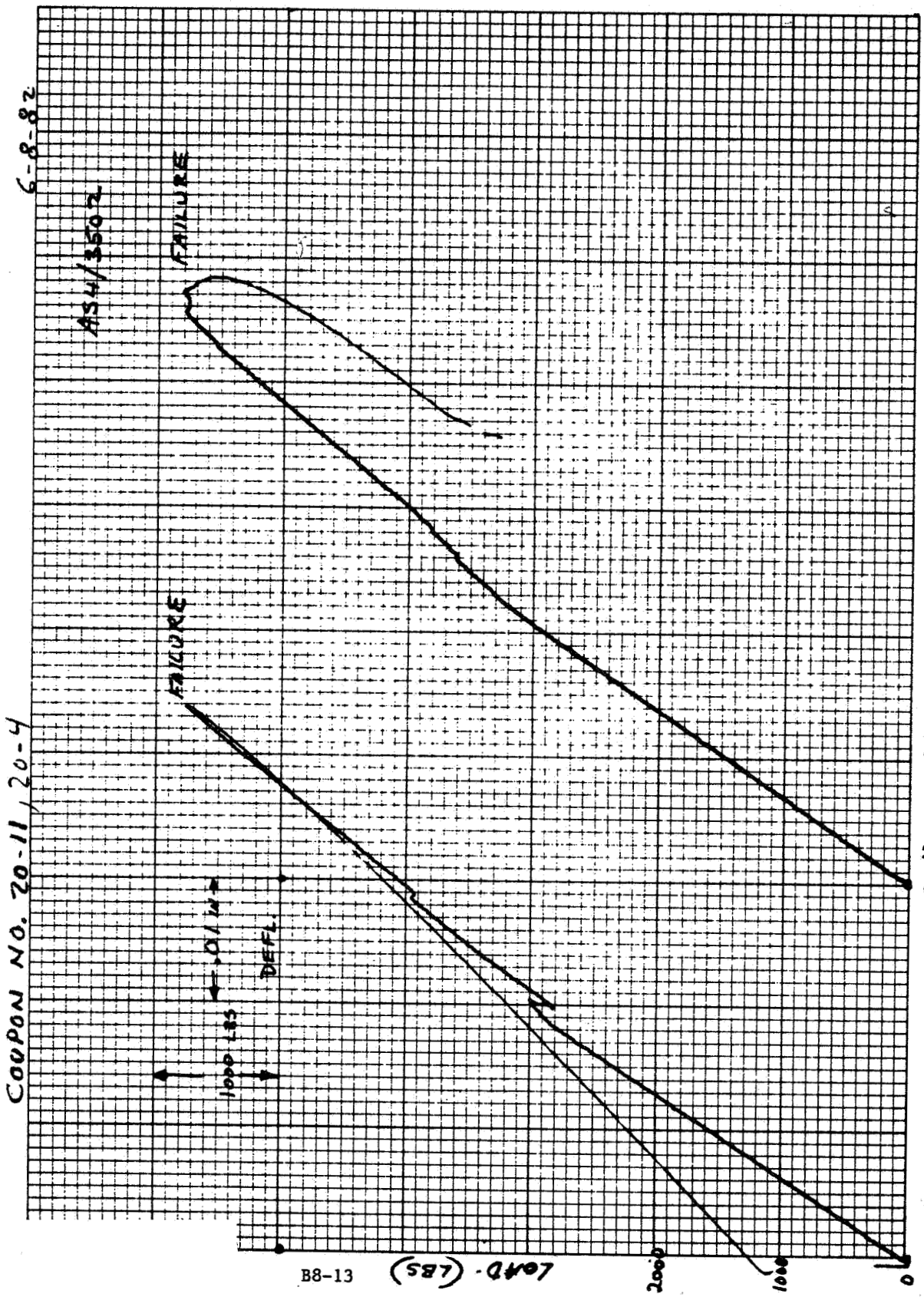

COUPON 19-5, 39-1, 39-2
SPEC 19-5 ASM/3502
SPEC 39-X ASM/2220-1
500# = .005"
DEFLECTION
BC-10
LOAD (LBS)
1000
500
0
19-5
39-1
39-2

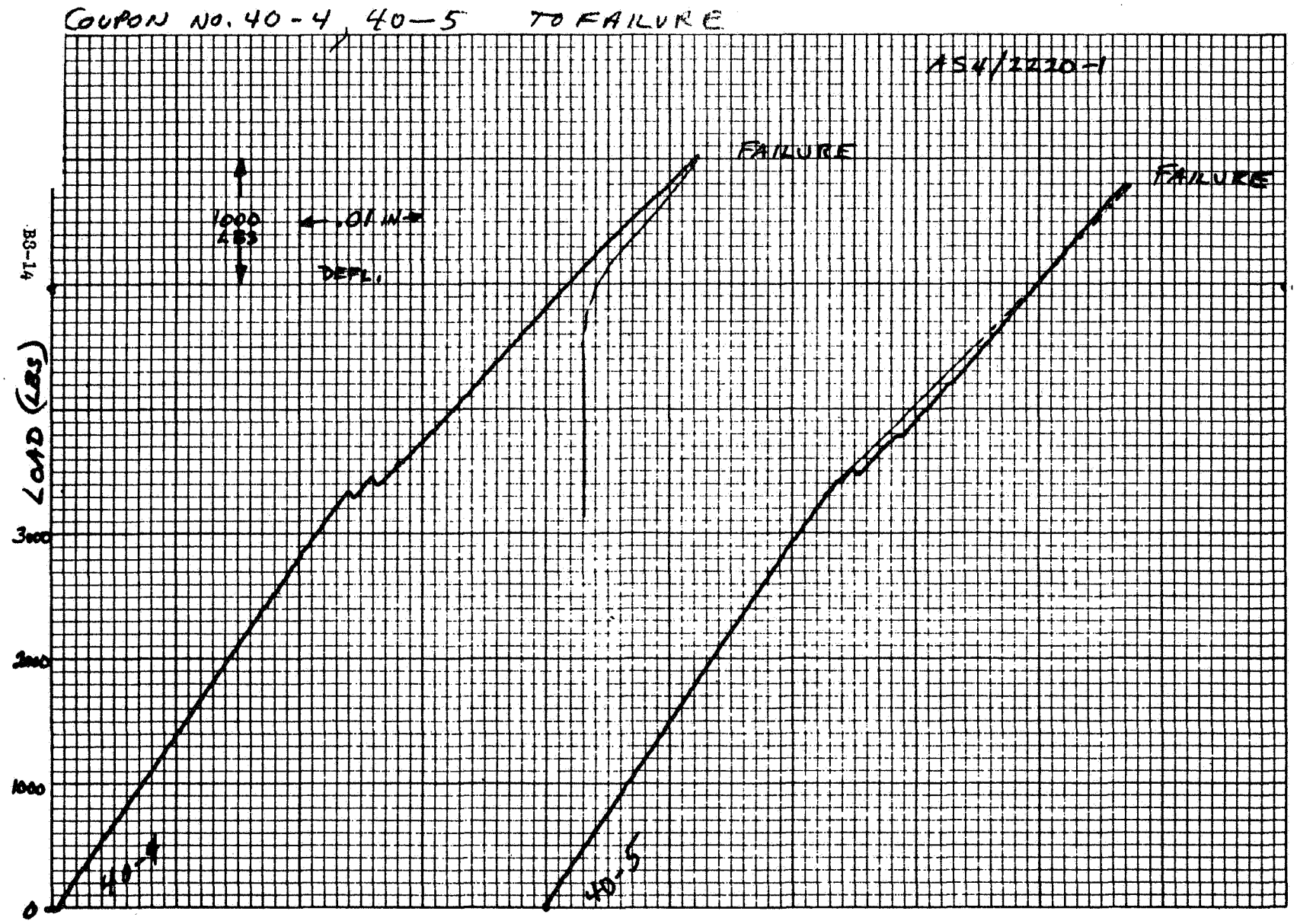
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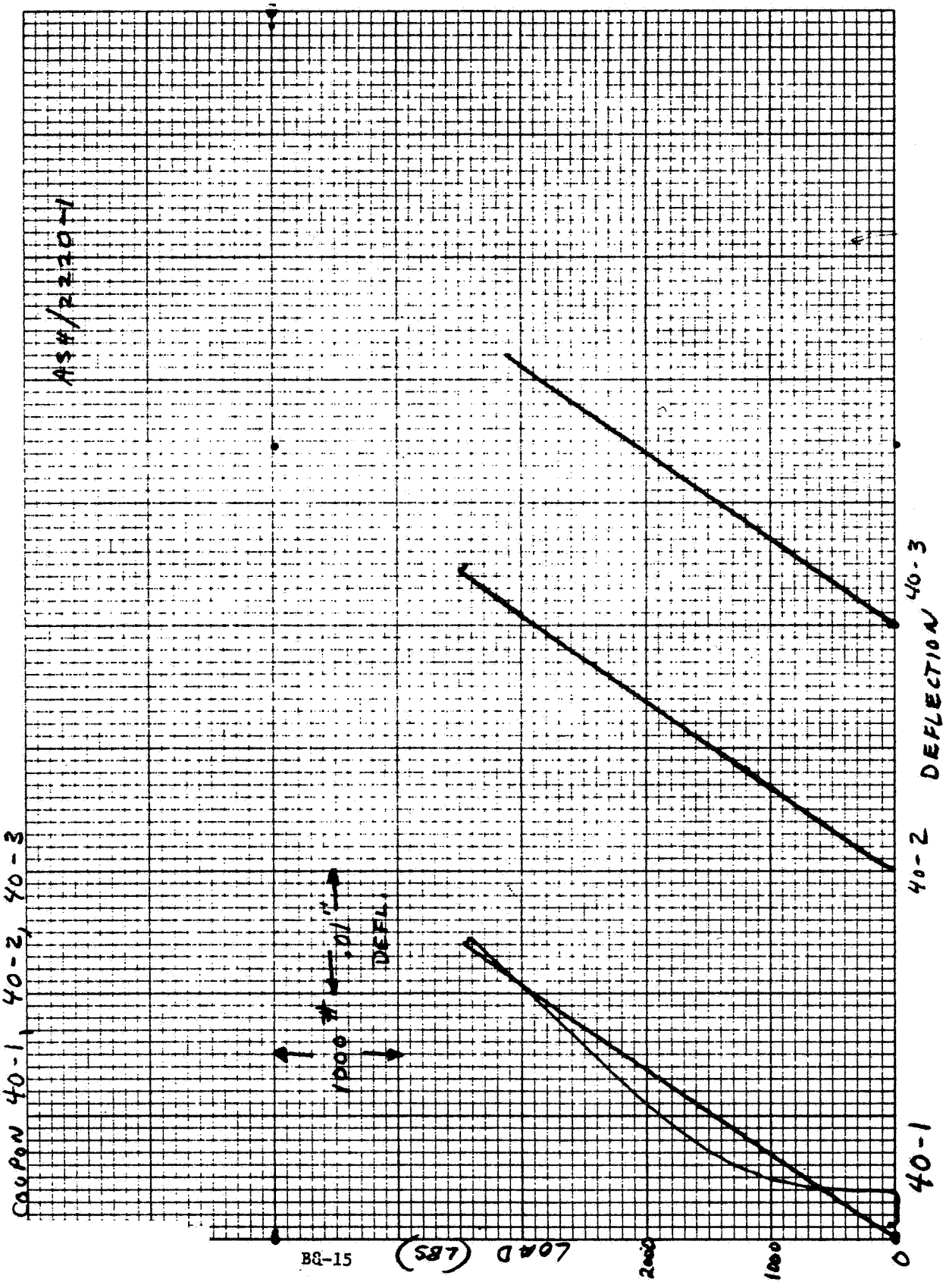


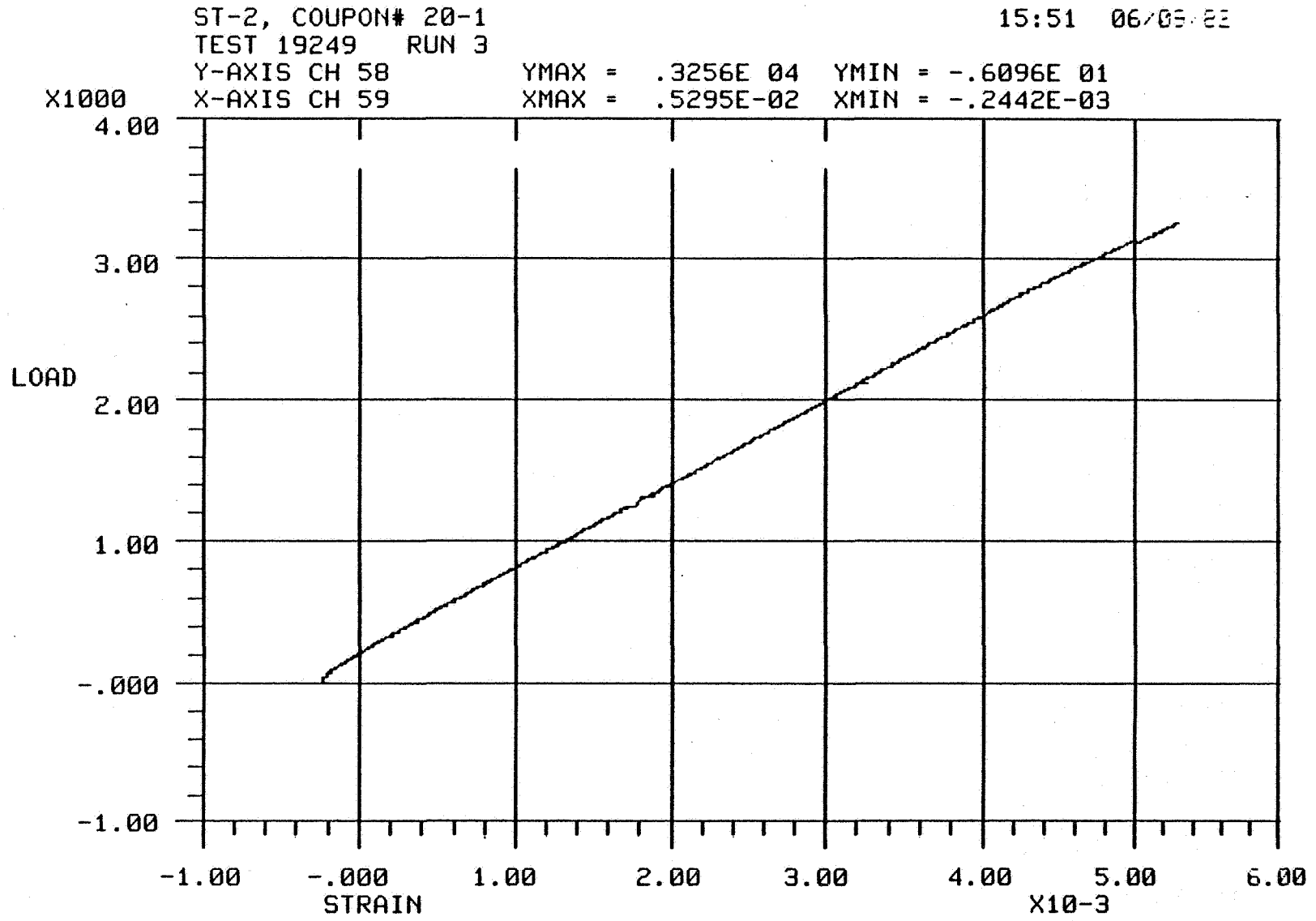
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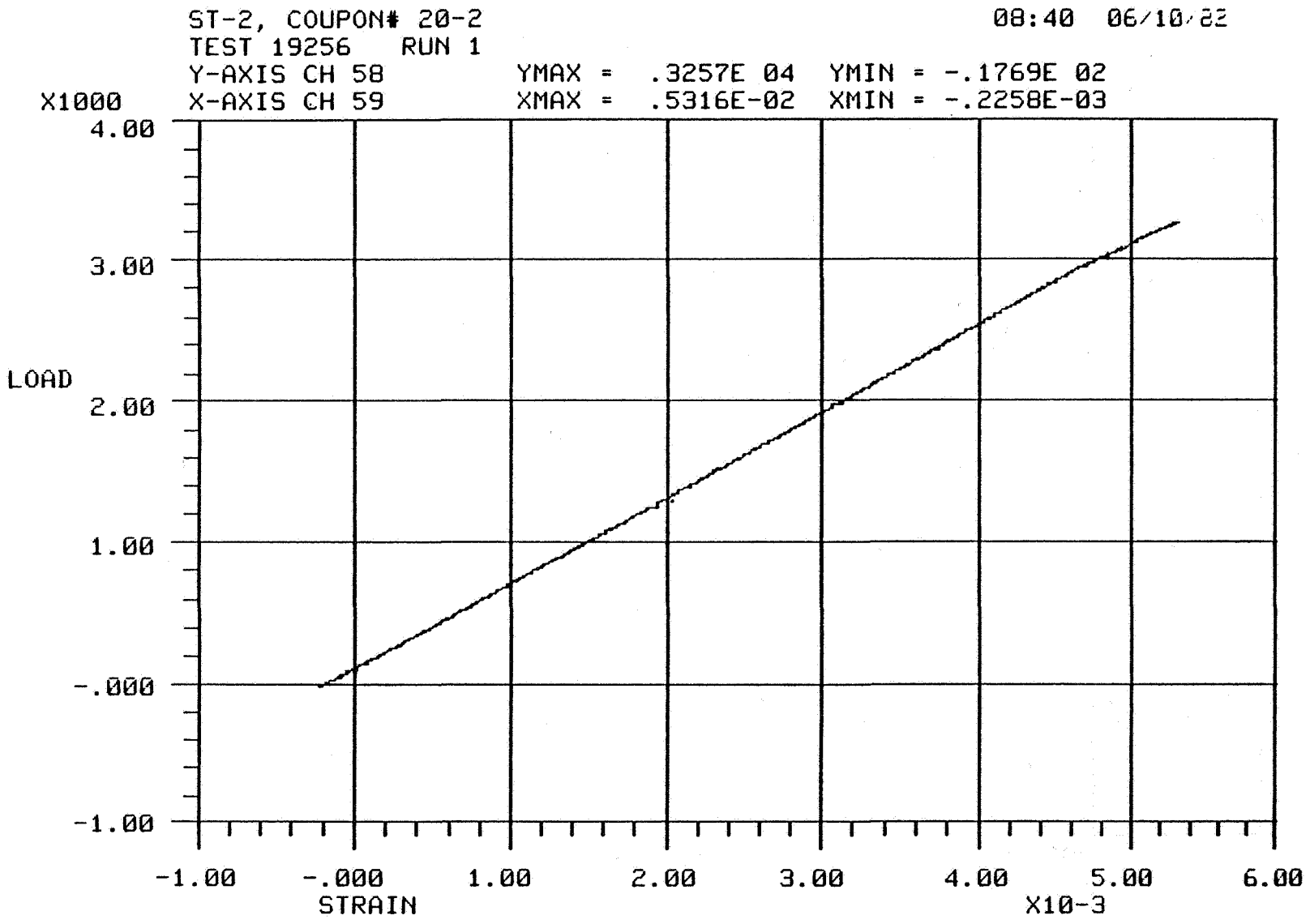


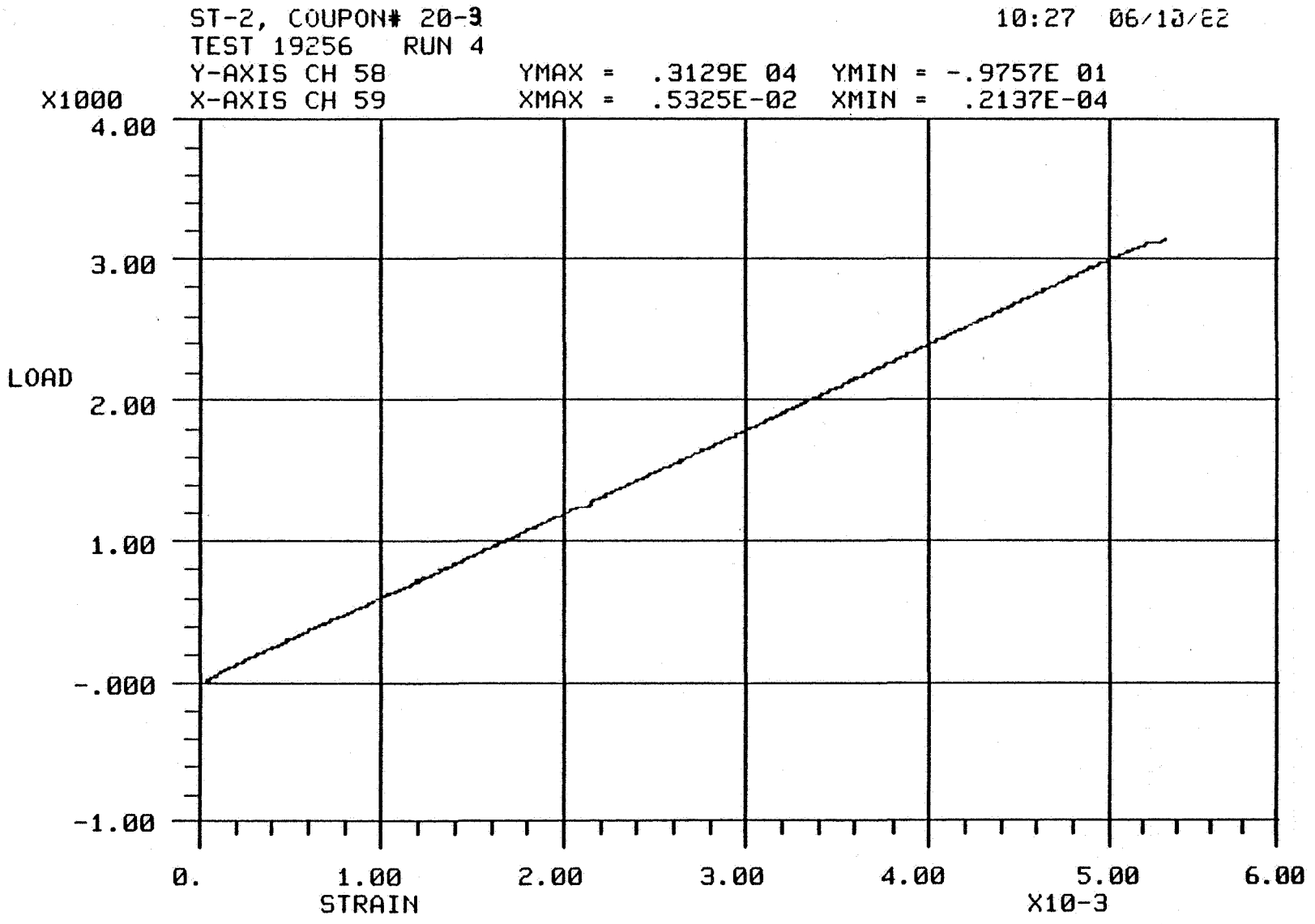

COUPON NO. 40-4, 40-5 TO FAILURE
AS4/2220-1
FAILURE
FAILURE
1000 LBS
.01 IN
DEFL.
LOAD (LBS)
3000
2000
1000
0
40-4
40-5
BS-14

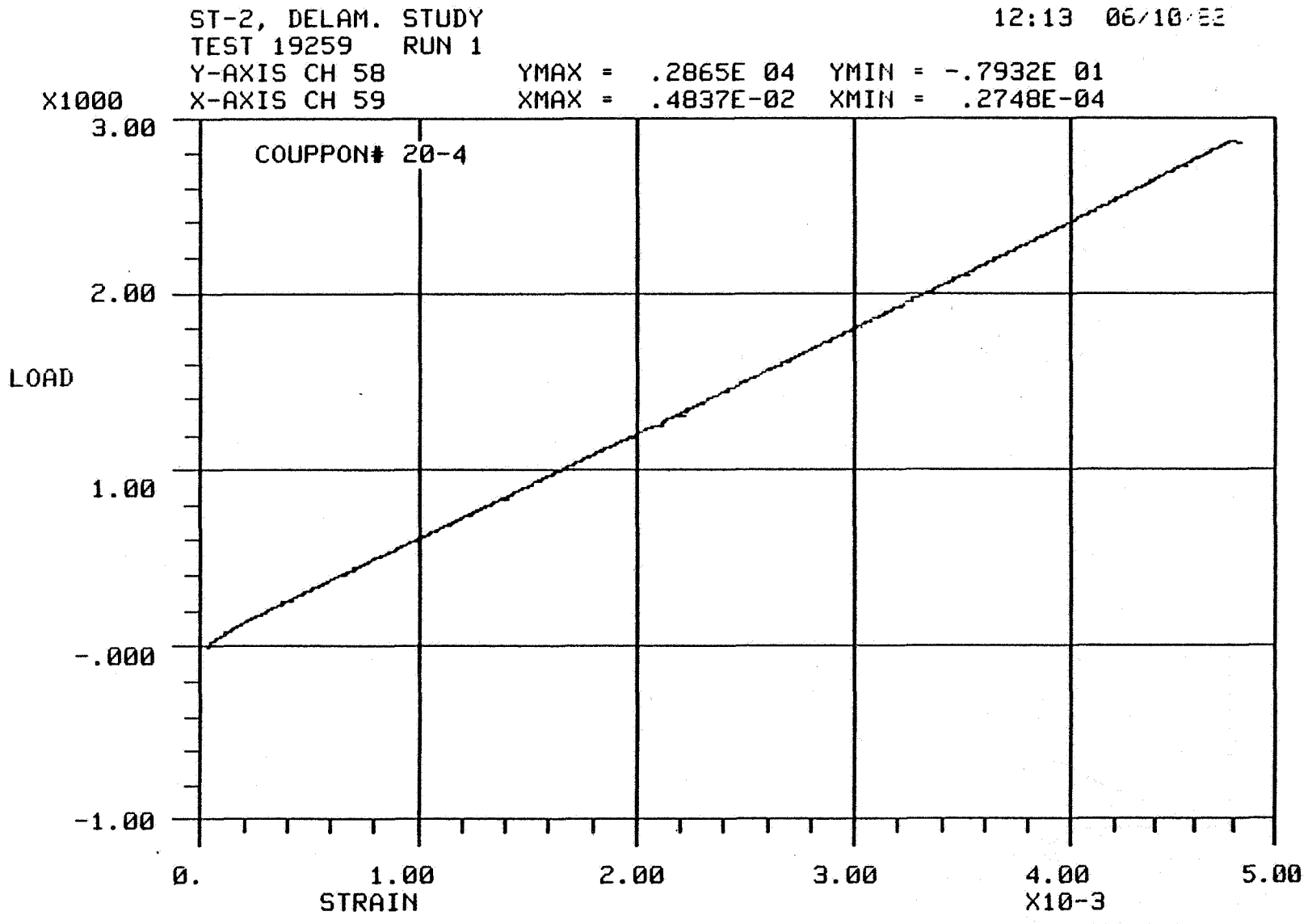
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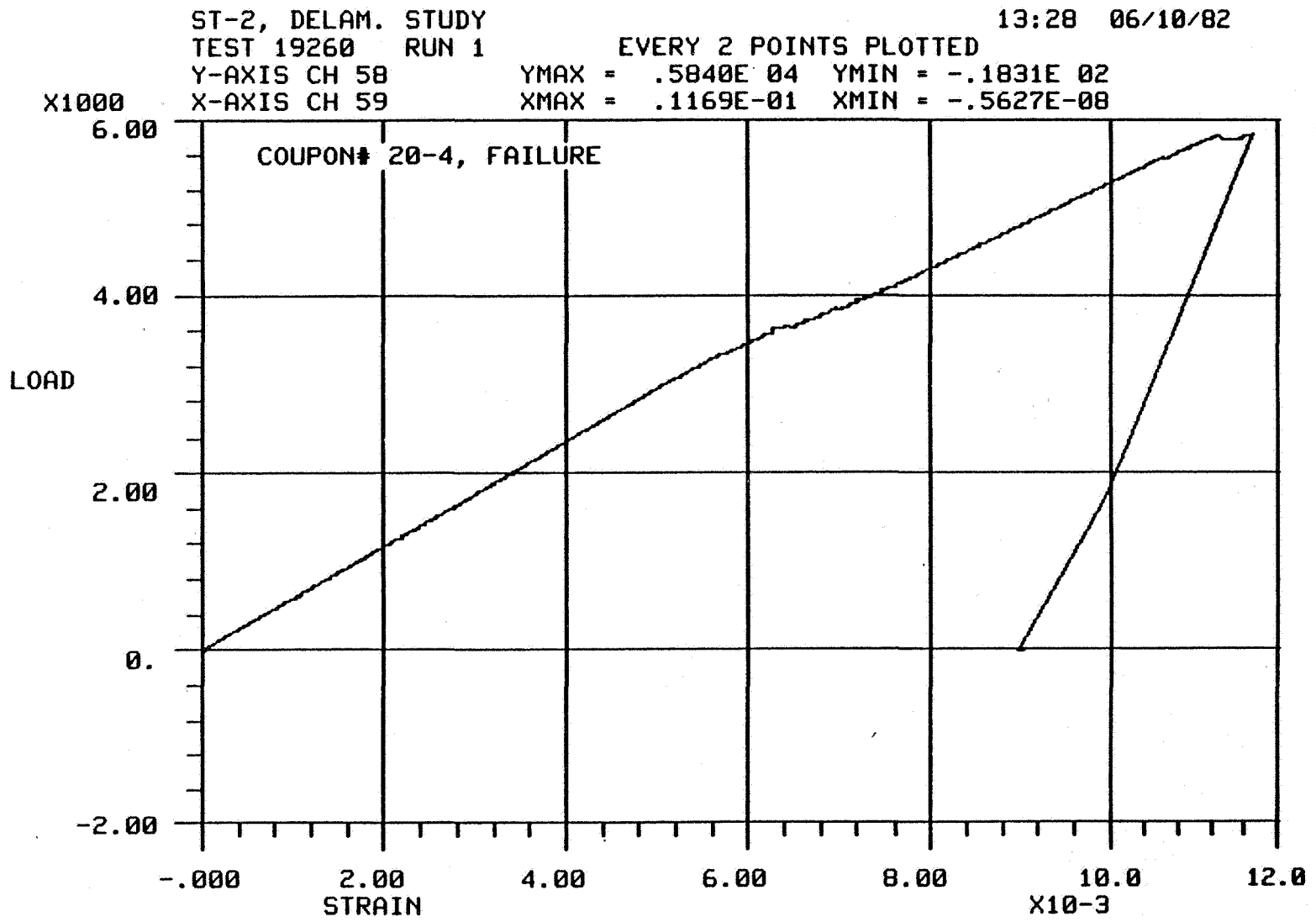


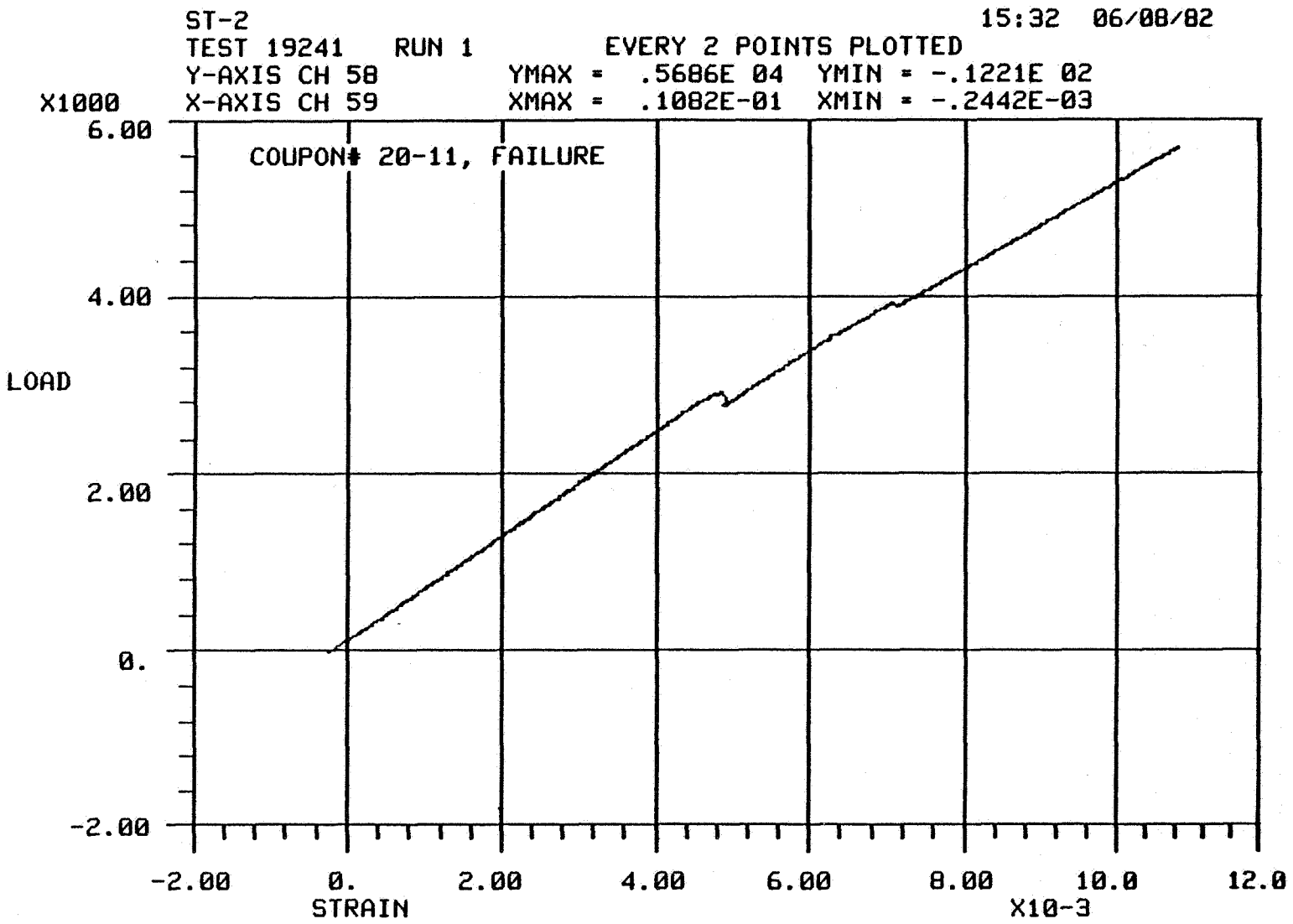

ST-2, COUPON# 20-1
TEST 19249 RUN 3
15:51 06/03/22
Y-AXIS CH 58 YMAX = .3256E 04 YMIN = -.6096E 01
X-AXIS CH 59 XMAX = .5295E-02 XMIN = -.2442E-03
X1000
4.00
3.00
2.00
1.00
-.000
-1.00
LOAD
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
6.00
STRAIN
X10-3

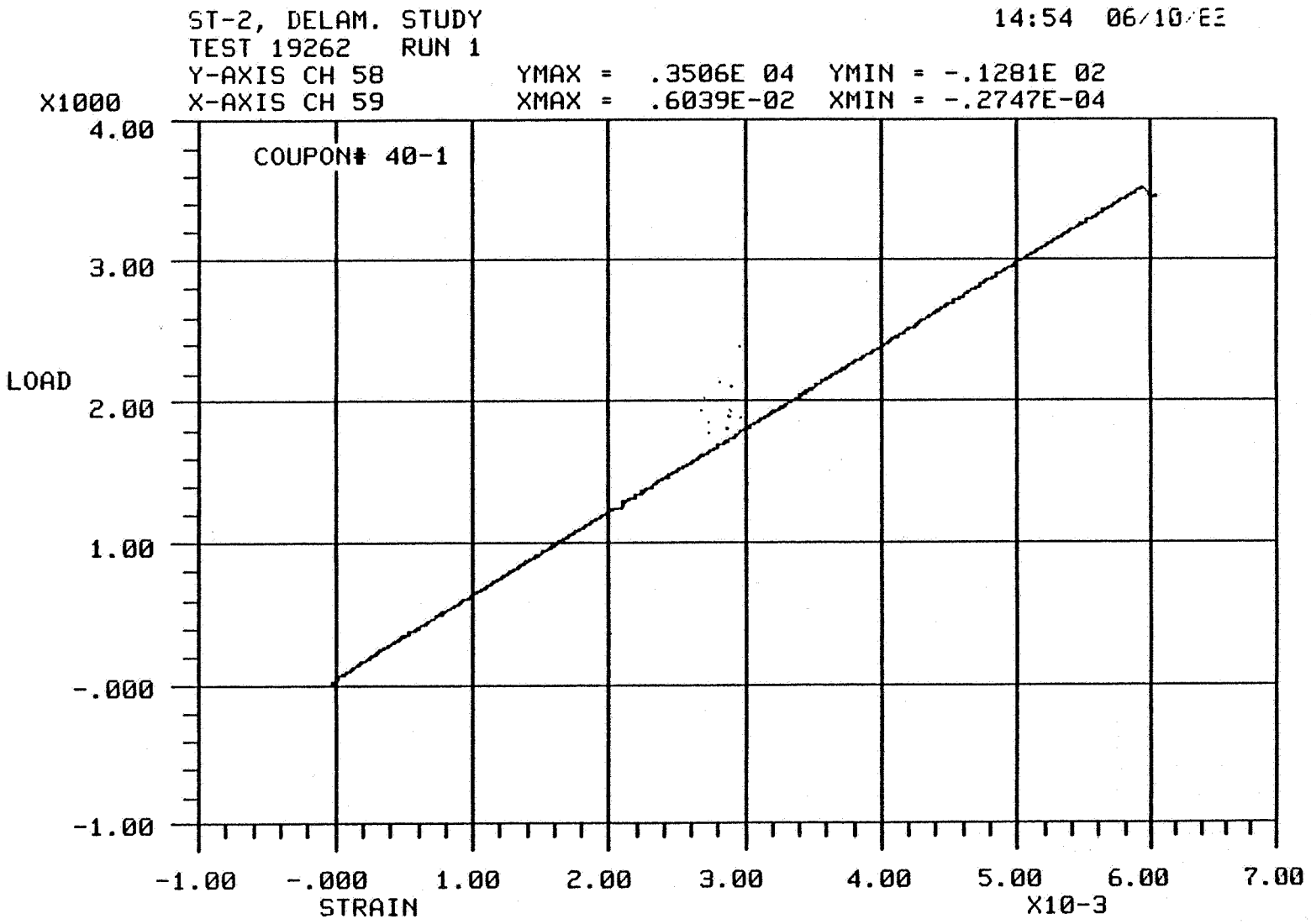

ST-2, COUPON# 20-2
08:40 06/10/22
TEST 19256 RUN 1
Y-AXIS CH 58
YMAX = .3257E 04
YMIN = -.1769E 02
X1000
X-AXIS CH 59
XMAX = .5316E-02
XMIN = -.2258E-03
4.00
3.00
LOAD
2.00
1.00
-.000
-1.00
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
6.00
STRAIN
X10-3

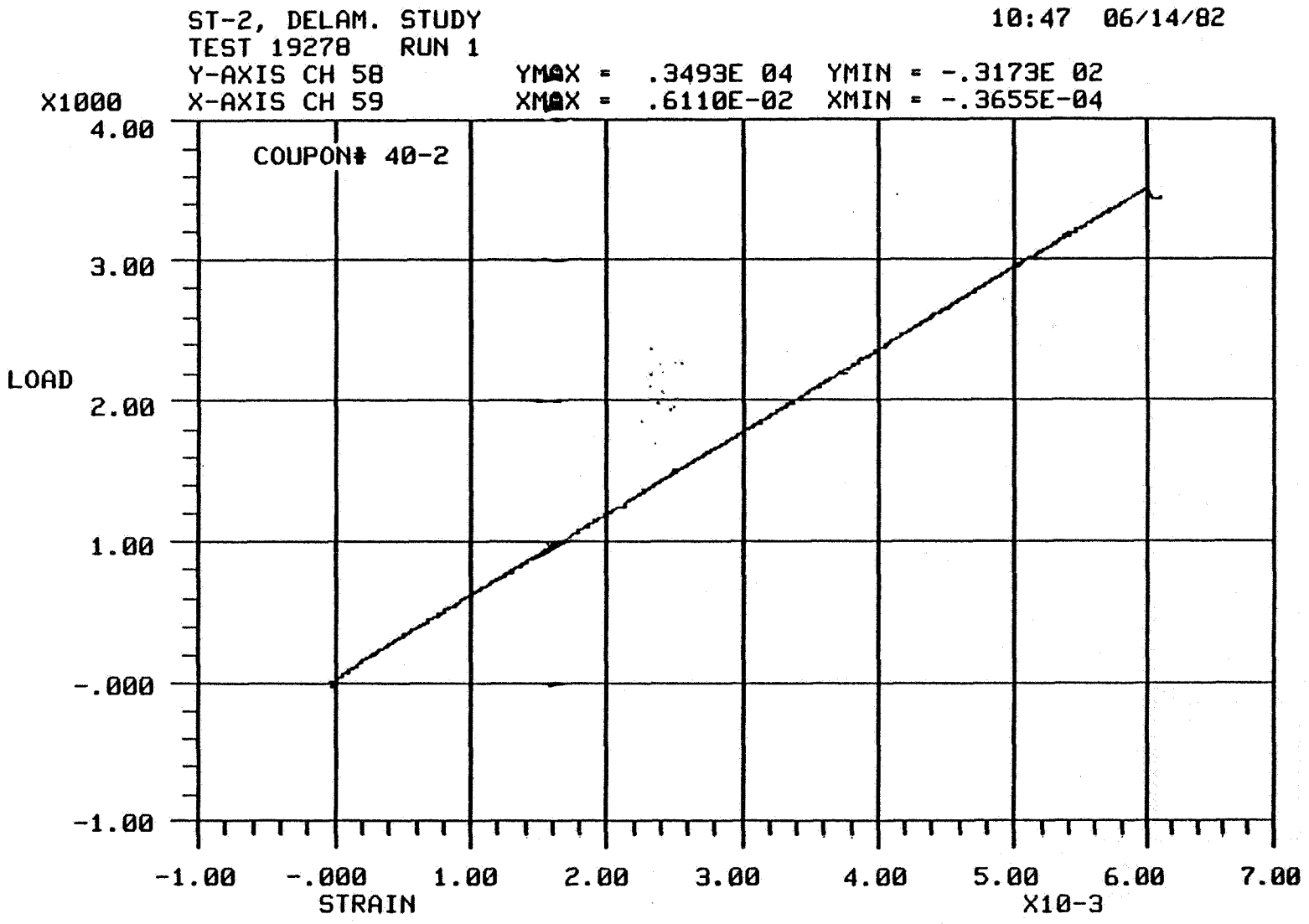

ST-2, COUPON# 20-3
10:27 06/10/82
TEST 19256 RUN 4
Y-AXIS CH 58
YMAX = .3129E 04
YMIN = -.9757E 01
X1000
X-AXIS CH 59
XMAX = .5325E-02
XMIN = .2137E-04
4.00
3.00
LOAD
2.00
1.00
-.000
-1.00
0.
1.00
2.00
3.00
4.00
5.00
6.00
STRAIN
X10-3

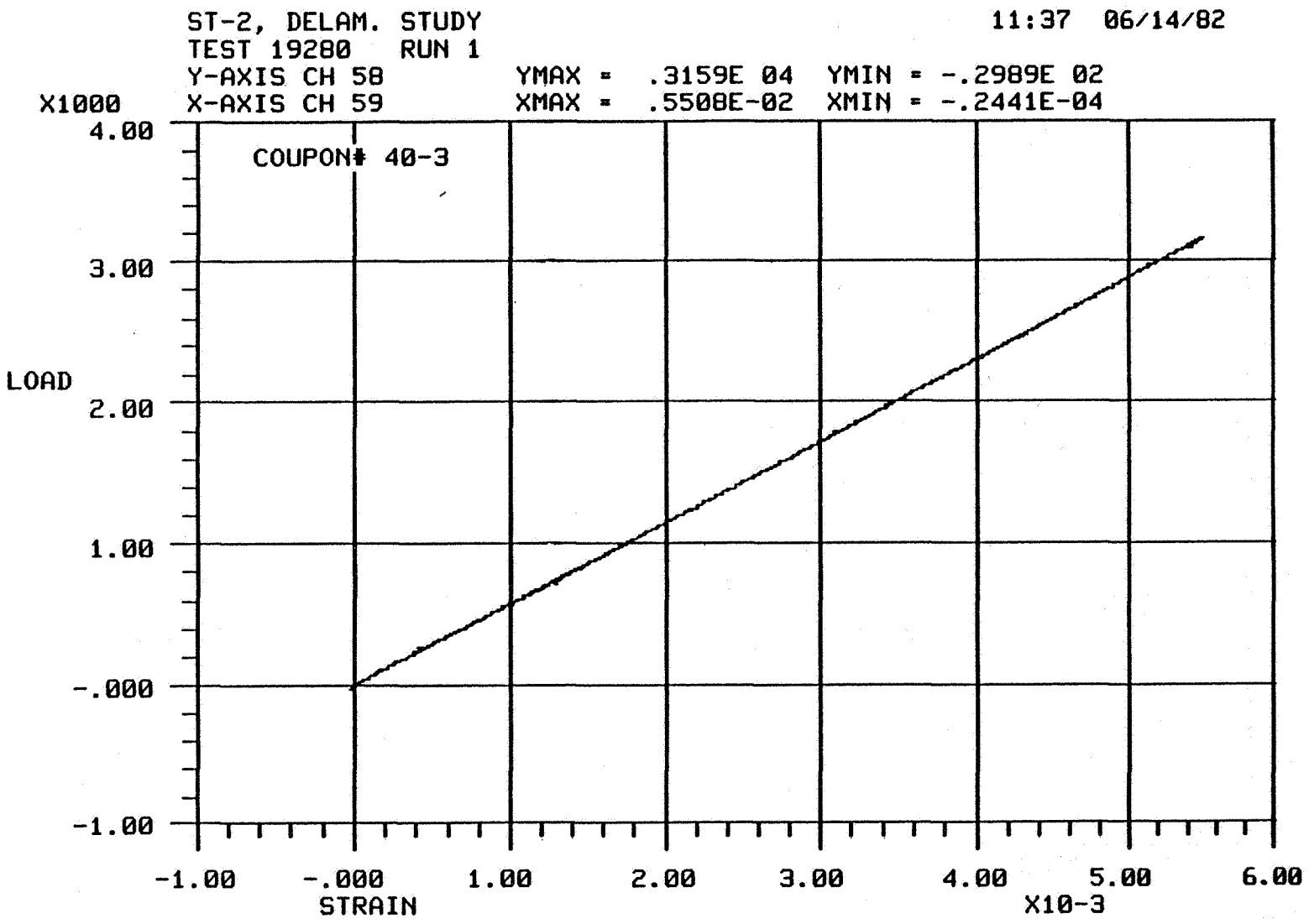

ST-2, DELAM. STUDY
12:13 06/10/88
TEST 19259 RUN 1
Y-AXIS CH 58 YMAX = .2865E 04 YMIN = -.7932E 01
X1000 X-AXIS CH 59 XMAX = .4837E-02 XMIN = .2748E-04
COUPPON# 20-4
3.00
2.00
1.00
-.000
-1.00
LOAD
0.
1.00
2.00
3.00
4.00
5.00
STRAIN
X10-3

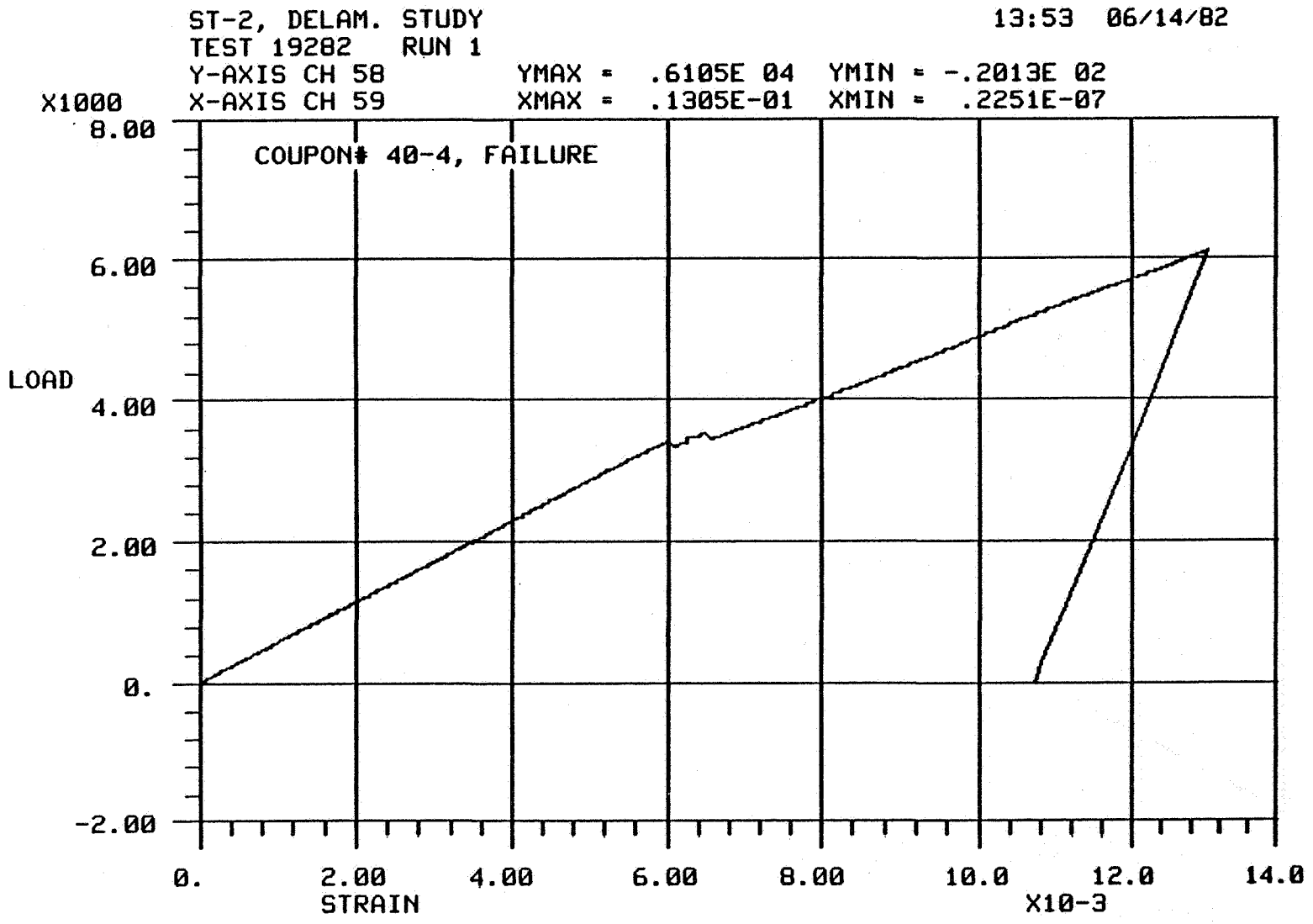

ST-2, DELAM. STUDY
13:28 06/10/82
TEST 19260 RUN 1
EVERY 2 POINTS PLOTTED
Y-AXIS CH 58
YMAX = .5840E 04 YMIN = -.1831E 02
X1000
X-AXIS CH 59
XMAX = .1169E-01 XMIN = -.5627E-08
COUPON# 20-4, FAILURE
6.00
4.00
2.00
0.
-2.00
LOAD
-.000
2.00
4.00
6.00
8.00
10.0
12.0
STRAIN
X10-3

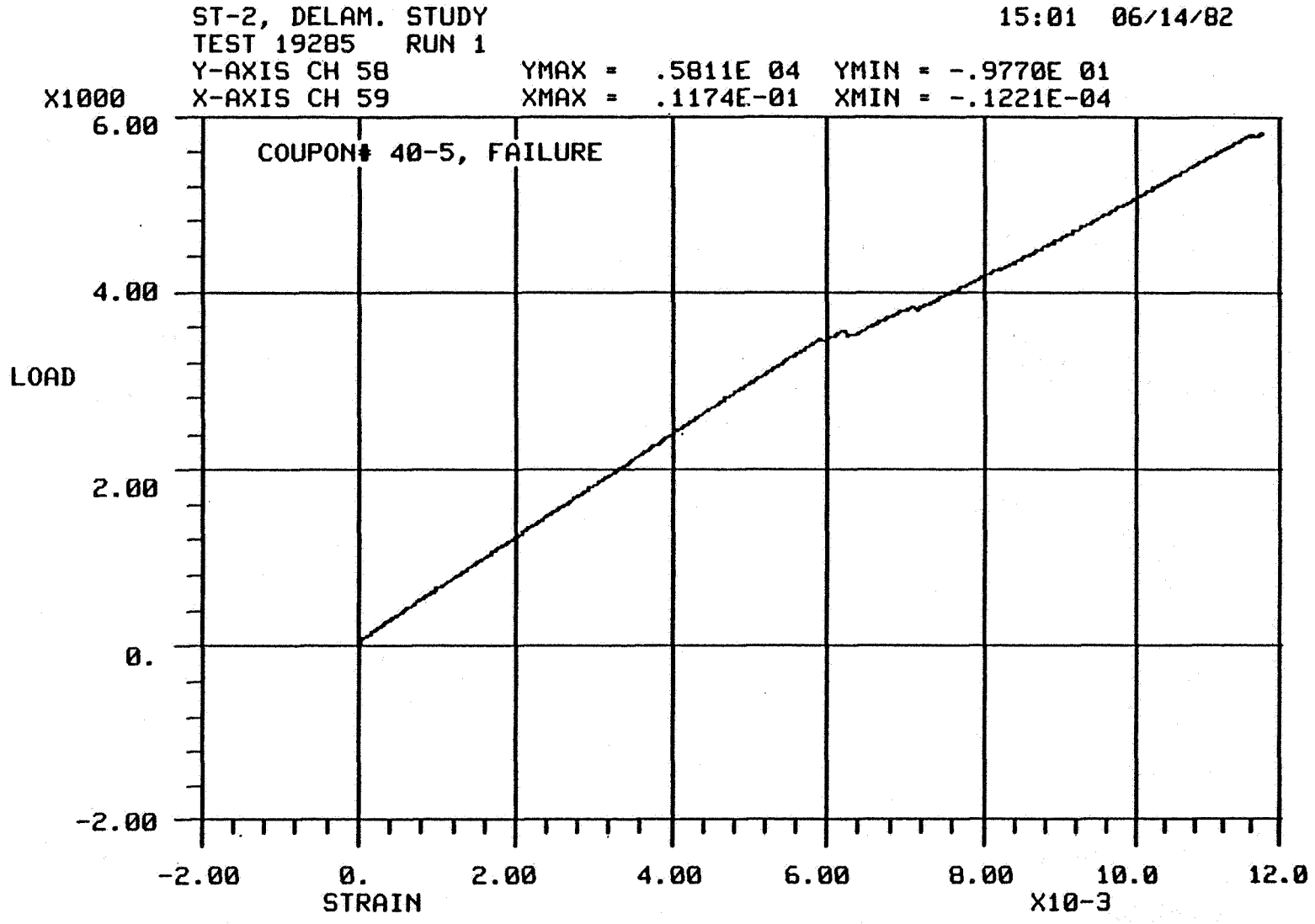

ST-2
15:32 06/08/82
TEST 19241 RUN 1
EVERY 2 POINTS PLOTTED
Y-AXIS CH 58
YMAX = .5686E 04 YMIN = -.1221E 02
X1000
X-AXIS CH 59
XMAX = .1082E-01 XMIN = -.2442E-03
COUPON# 20-11, FAILURE
6.00
4.00
2.00
0.
-2.00
LOAD
-2.00
0.
2.00
4.00
6.00
8.00
10.0
12.0
STRAIN
X10-3

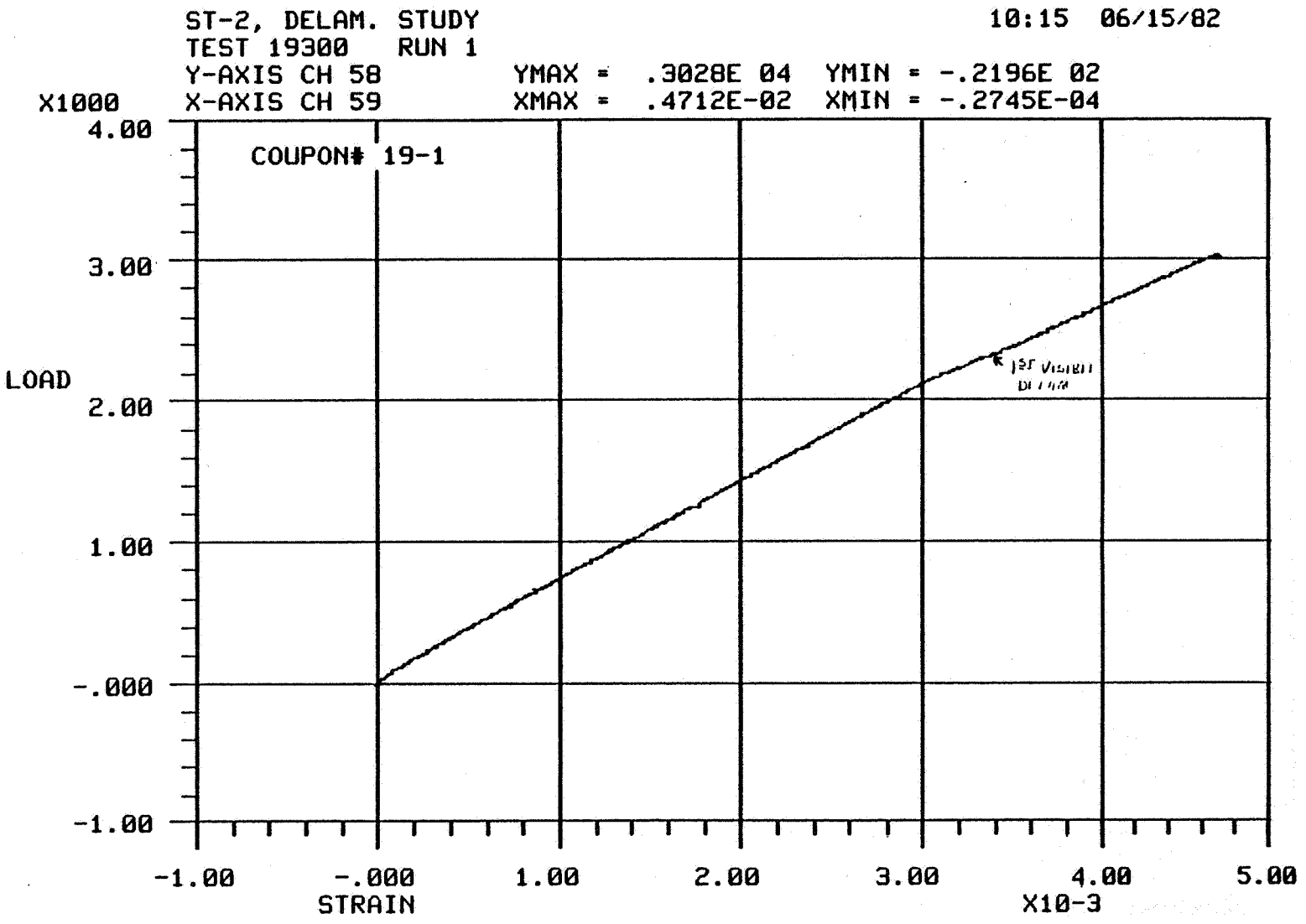

ST-2, DELAM. STUDY
14:54 06/10/EE
TEST 19262 RUN 1
Y-AXIS CH 58 YMAX = .3506E 04 YMIN = -.1281E 02
X-AXIS CH 59 XMAX = .6039E-02 XMIN = -.2747E-04
X1000
COUPON# 40-1
LOAD
4.00
3.00
2.00
1.00
-.000
-1.00
-1.00 -.000 1.00 2.00 3.00 4.00 5.00 6.00 7.00
STRAIN
X10-3

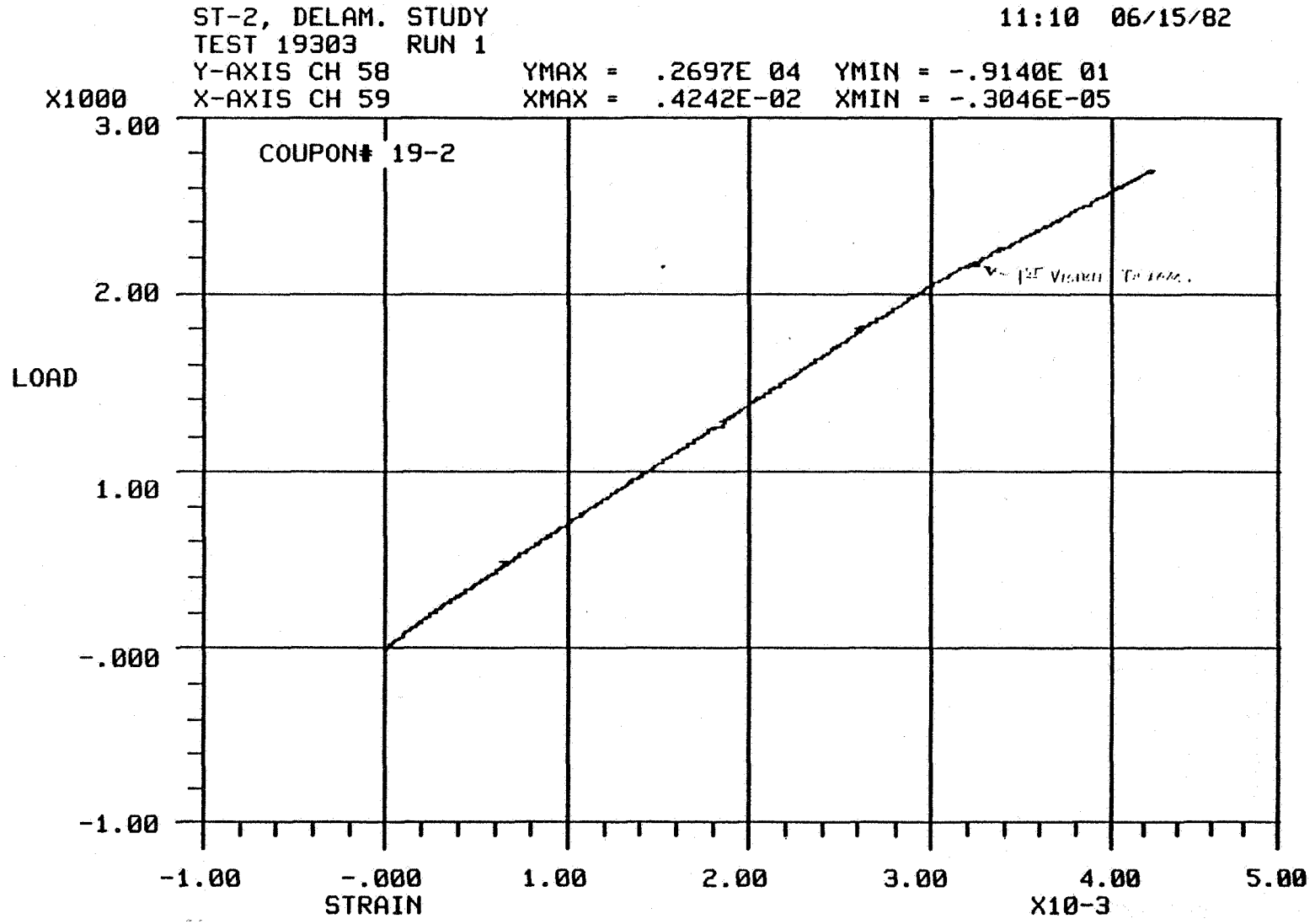

ST-2, DELAM. STUDY
10:47 06/14/82
TEST 19278 RUN 1
Y-AXIS CH 58
YMAX = .3493E 04 YMIN = -.3173E 02
X1000
X-AXIS CH 59
XMAX = .6110E-02 XMIN = -.3655E-04
COUPON# 40-2
4.00
3.00
2.00
1.00
-.000
-1.00
LOAD
-1.00 -.000 1.00 2.00 3.00 4.00 5.00 6.00 7.00
STRAIN
X10-3


ST-2, DELAM. STUDY
11:37 06/14/82
TEST 19280 RUN 1
Y-AXIS CH 58
YMAX = .3159E 04
YMIN = -.2989E 02
X1000
X-AXIS CH 59
XMAX = .5508E-02
XMIN = -.2441E-04
COUPON# 40-3
4.00
3.00
2.00
1.00
-.000
-1.00
LOAD
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
6.00
STRAIN
X10-3

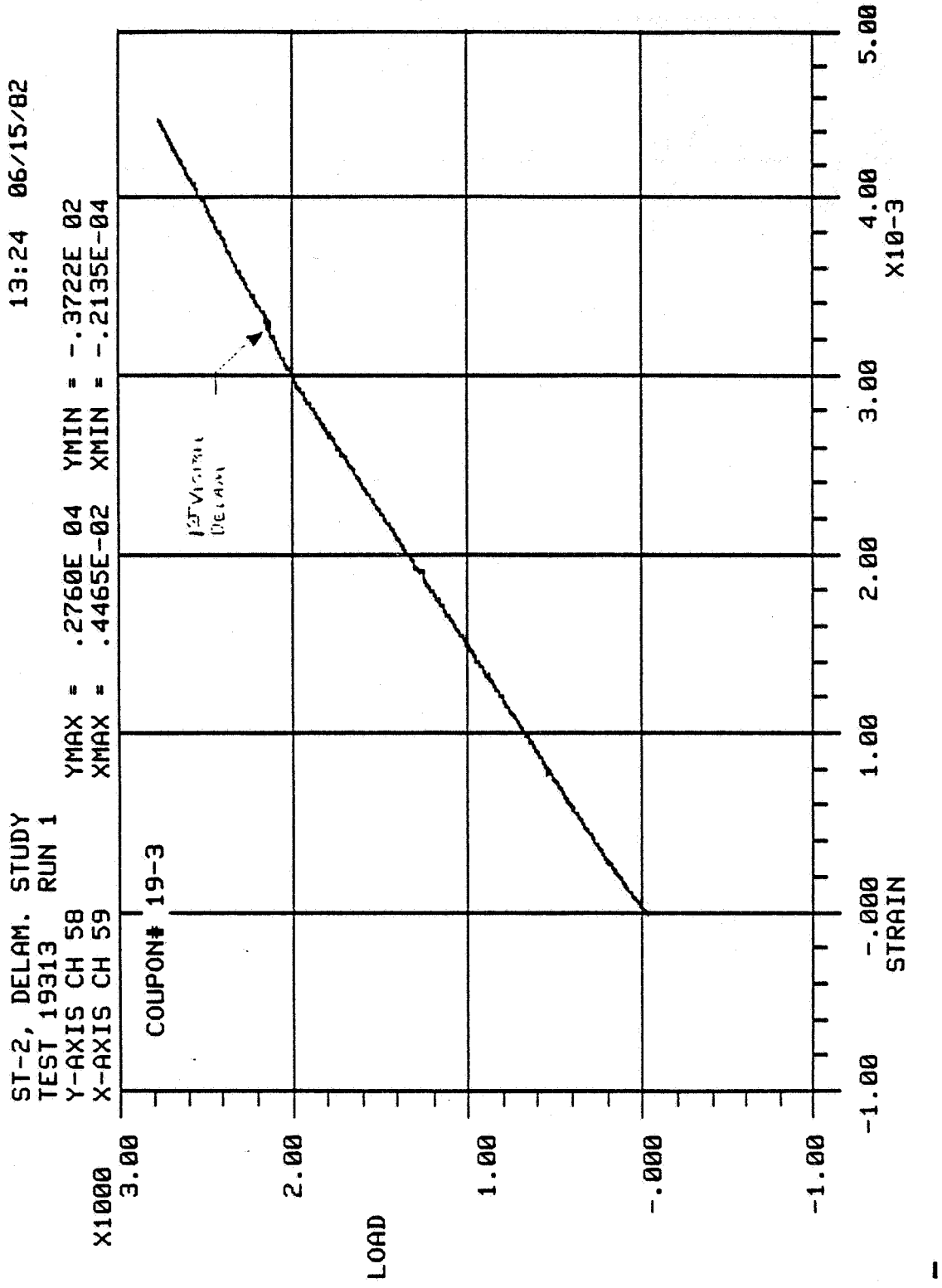

ST-2, DELAM. STUDY
13:53 06/14/82
TEST 19282 RUN 1
Y-AXIS CH 58 YMAX = .6105E 04 YMIN = -.2013E 02
X1000 X-AXIS CH 59 XMAX = .1305E-01 XMIN = .2251E-07
COUPON# 40-4, FAILURE
8.00
6.00
4.00
2.00
0.
-2.00
LOAD
0.
2.00
4.00
6.00
8.00
10.0
12.0
14.0
STRAIN
X10-3

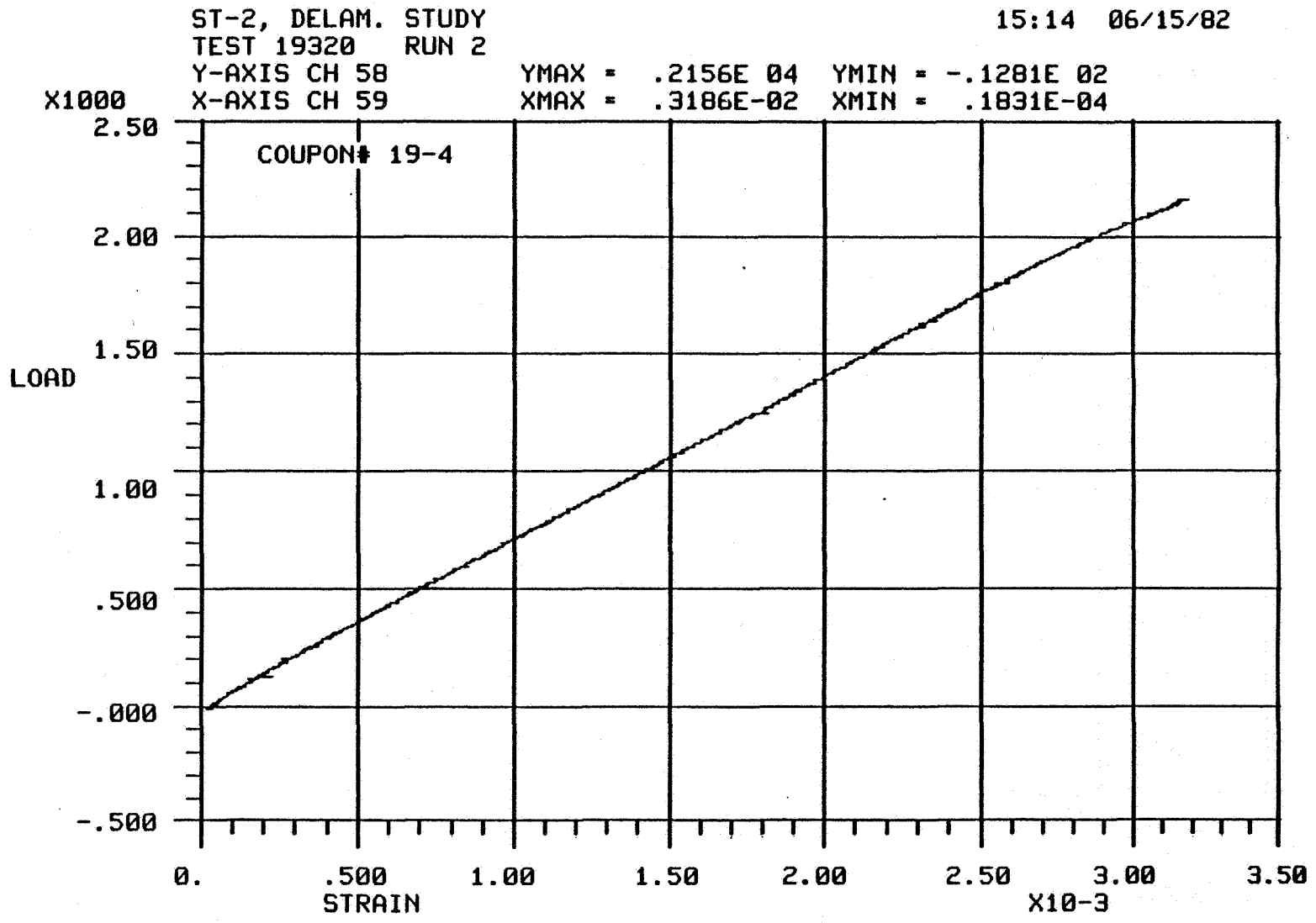

ST-2, DELAM. STUDY
15:01 06/14/82
TEST 19285 RUN 1
Y-AXIS CH 58 YMAX = .5811E 04 YMIN = -.9770E 01
X-AXIS CH 59 XMAX = .1174E-01 XMIN = -.1221E-04
X1000
COUPON# 40-5, FAILURE
6.00
4.00
2.00
0.
-2.00
LOAD
-2.00
0.
2.00
4.00
6.00
8.00
10.0
12.0
STRAIN
X10-3

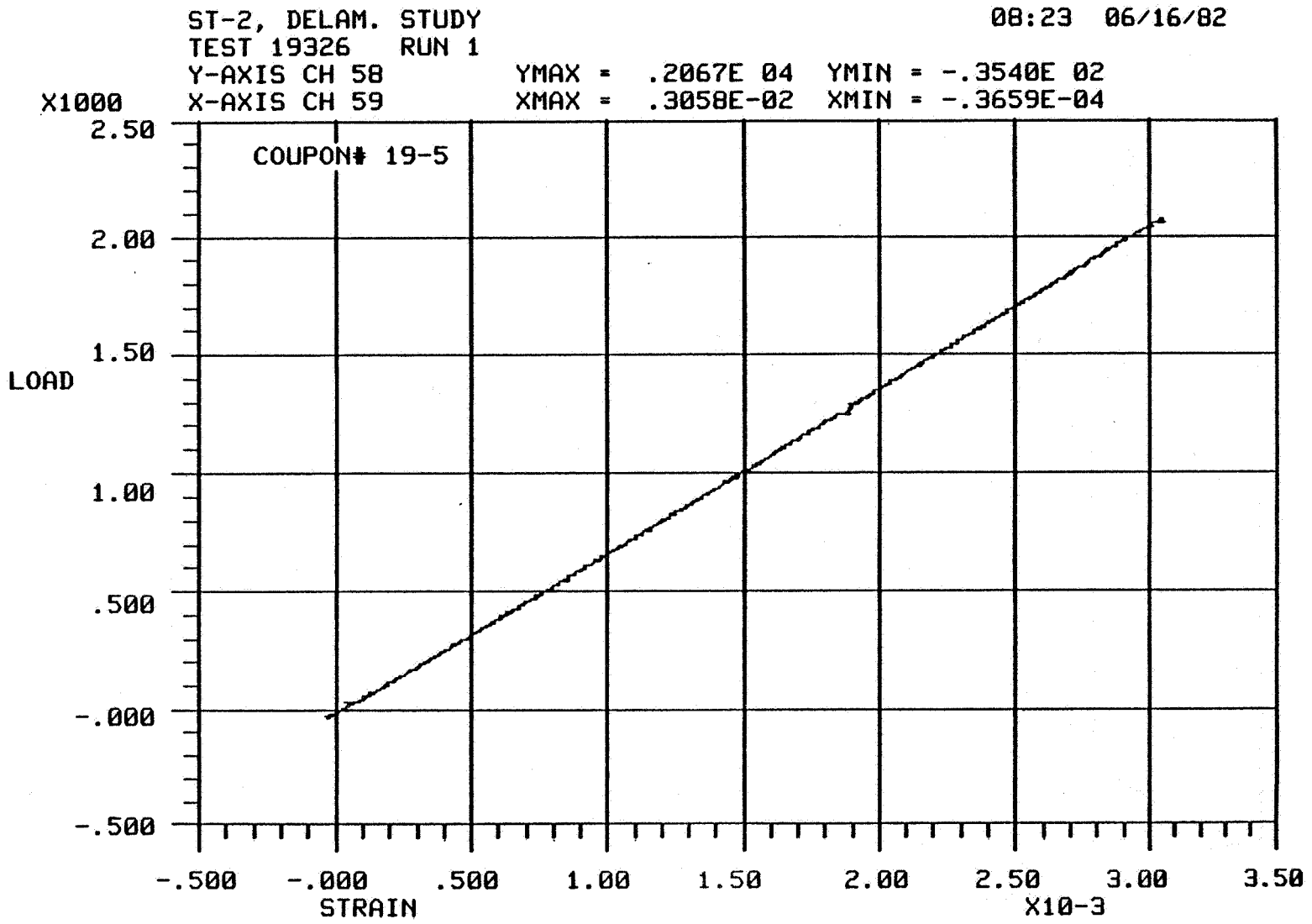

ST-2, DELAM. STUDY
10:15 06/15/82
TEST 19300 RUN 1
Y-AXIS CH 58 YMAX = .3028E 04 YMIN = -.2196E 02
X1000 X-AXIS CH 59 XMAX = .4712E-02 XMIN = -.2745E-04
COUPON# 19-1
LOAD
4.00
3.00
2.00
1.00
-.000
-1.00
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
STRAIN
X10-3

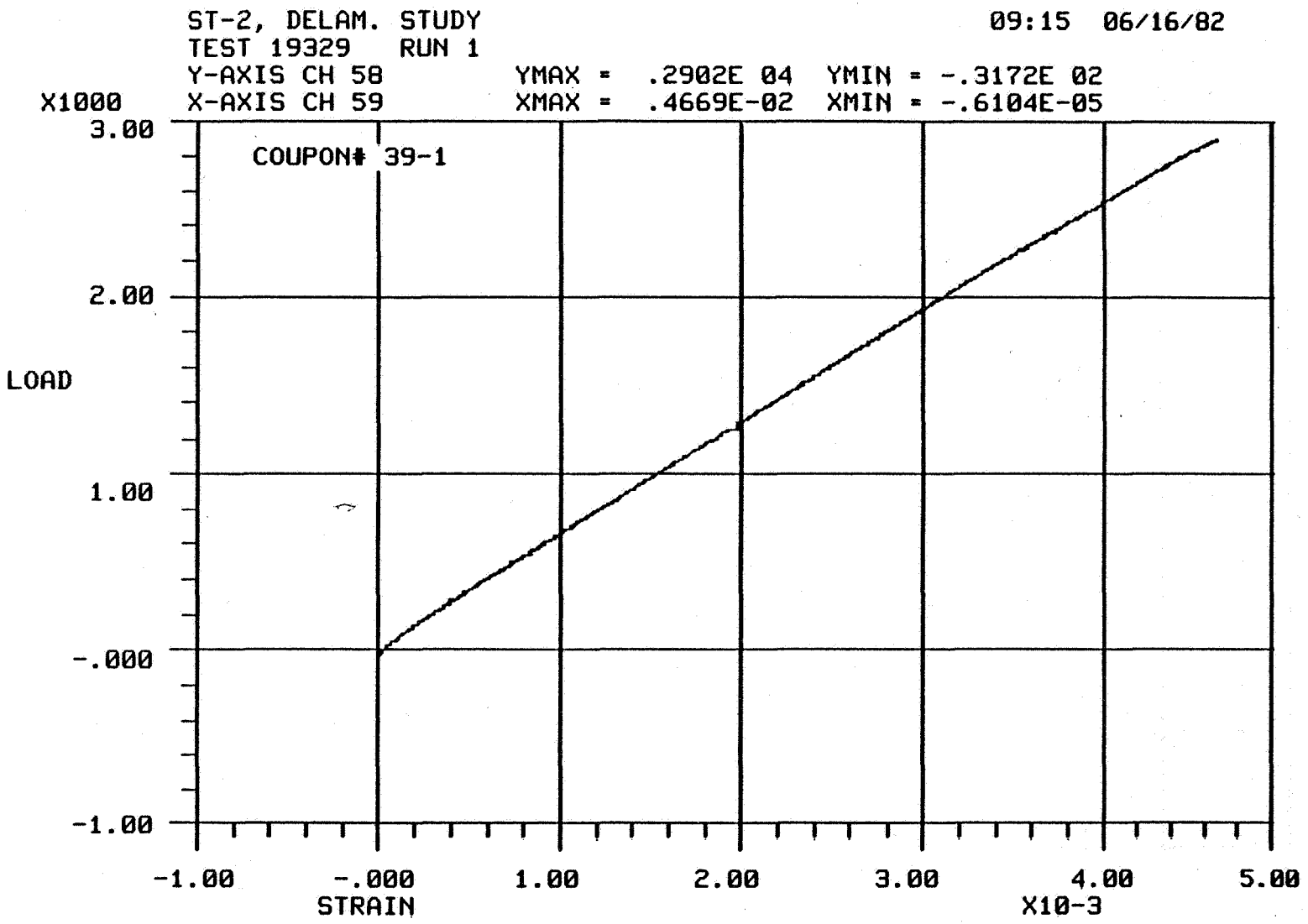

ST-2, DELAM. STUDY
11:10 06/15/82
TEST 19303 RUN 1
Y-AXIS CH 58
YMAX = .2697E 04 YMIN = -.9140E 01
X1000
X-AXIS CH 59
XMAX = .4242E-02 XMIN = -.3046E-05
3.00
COUPON# 19-2
2.00
LOAD
1.00
-.000
-1.00
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
STRAIN
X10-3

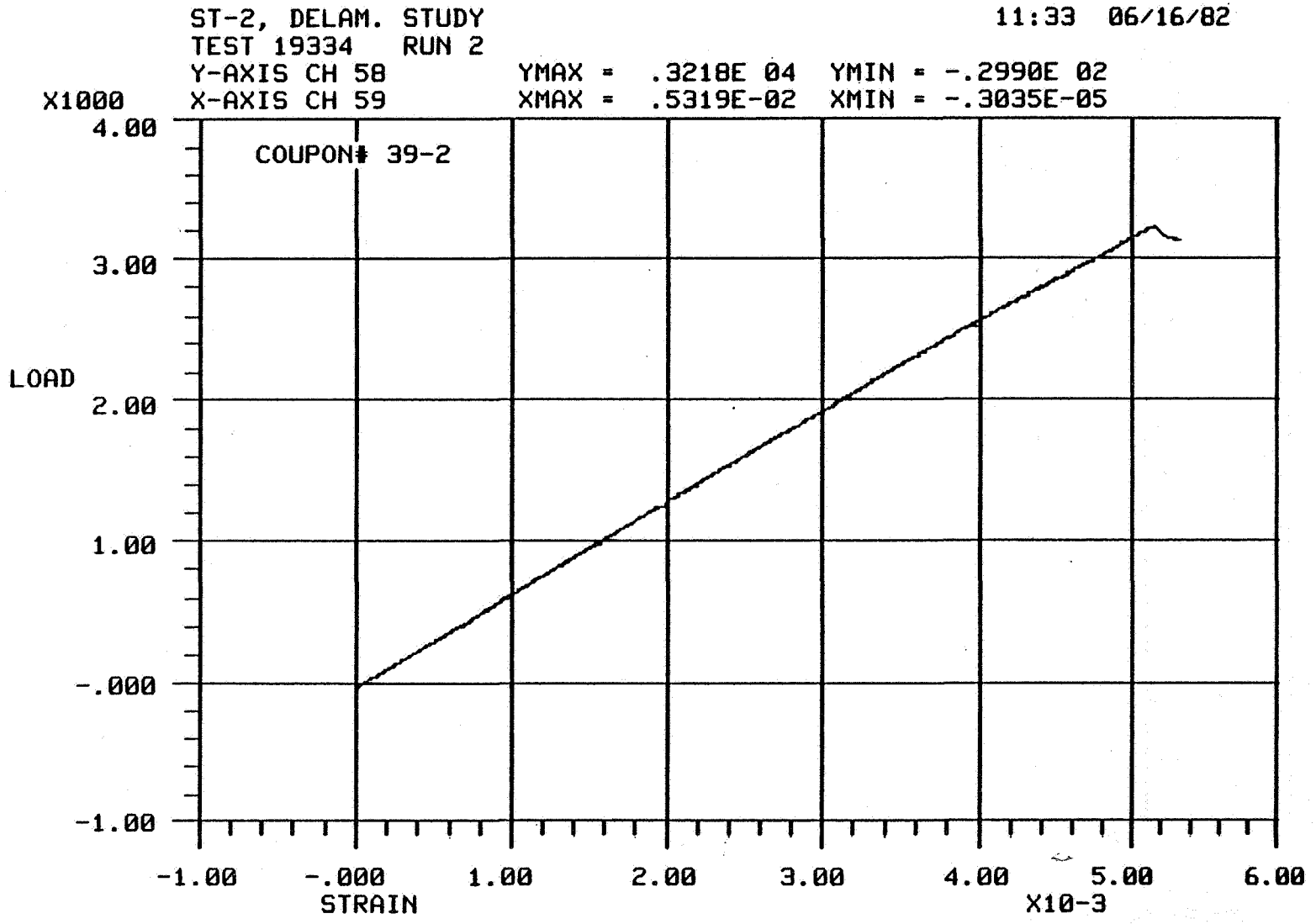
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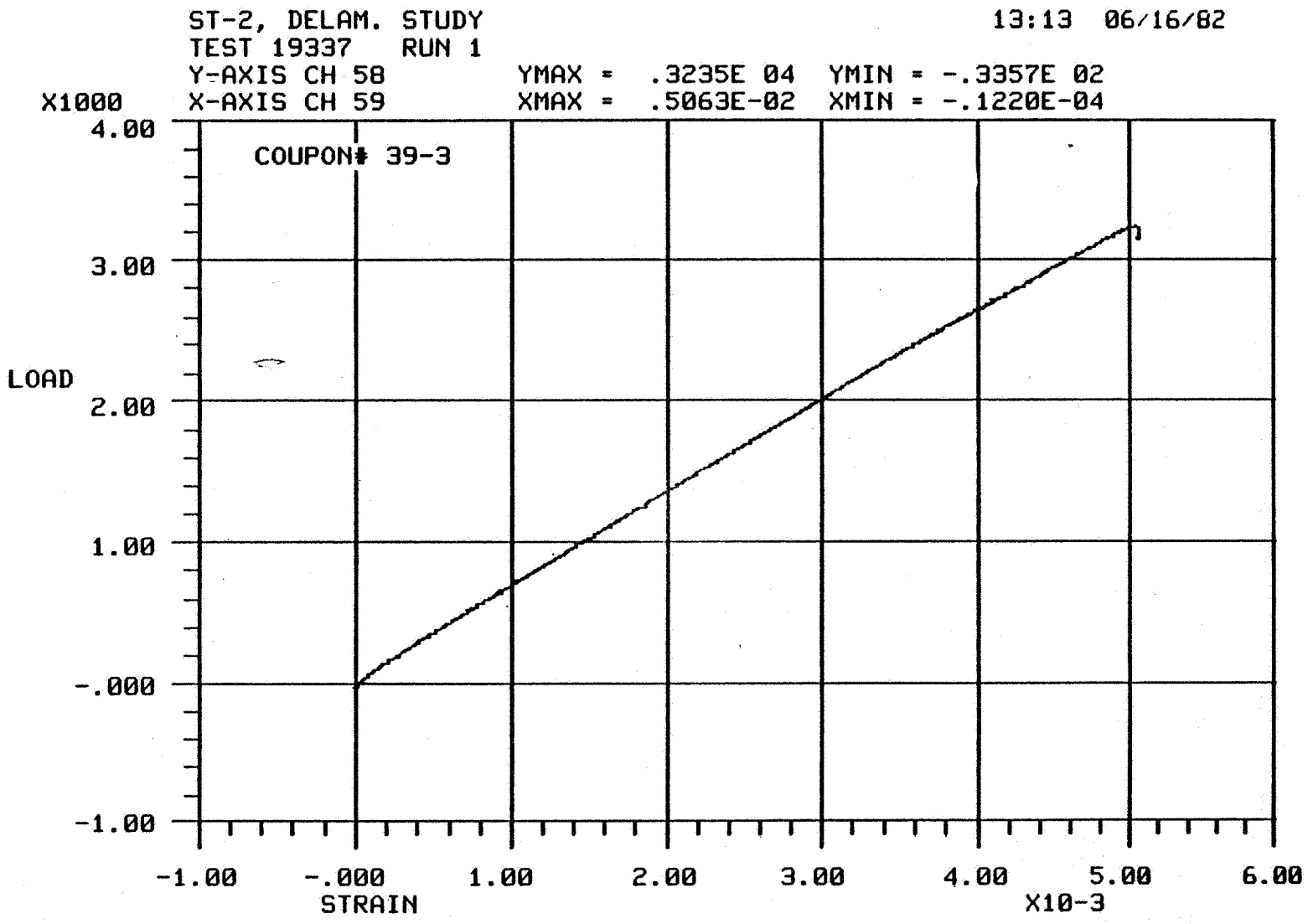


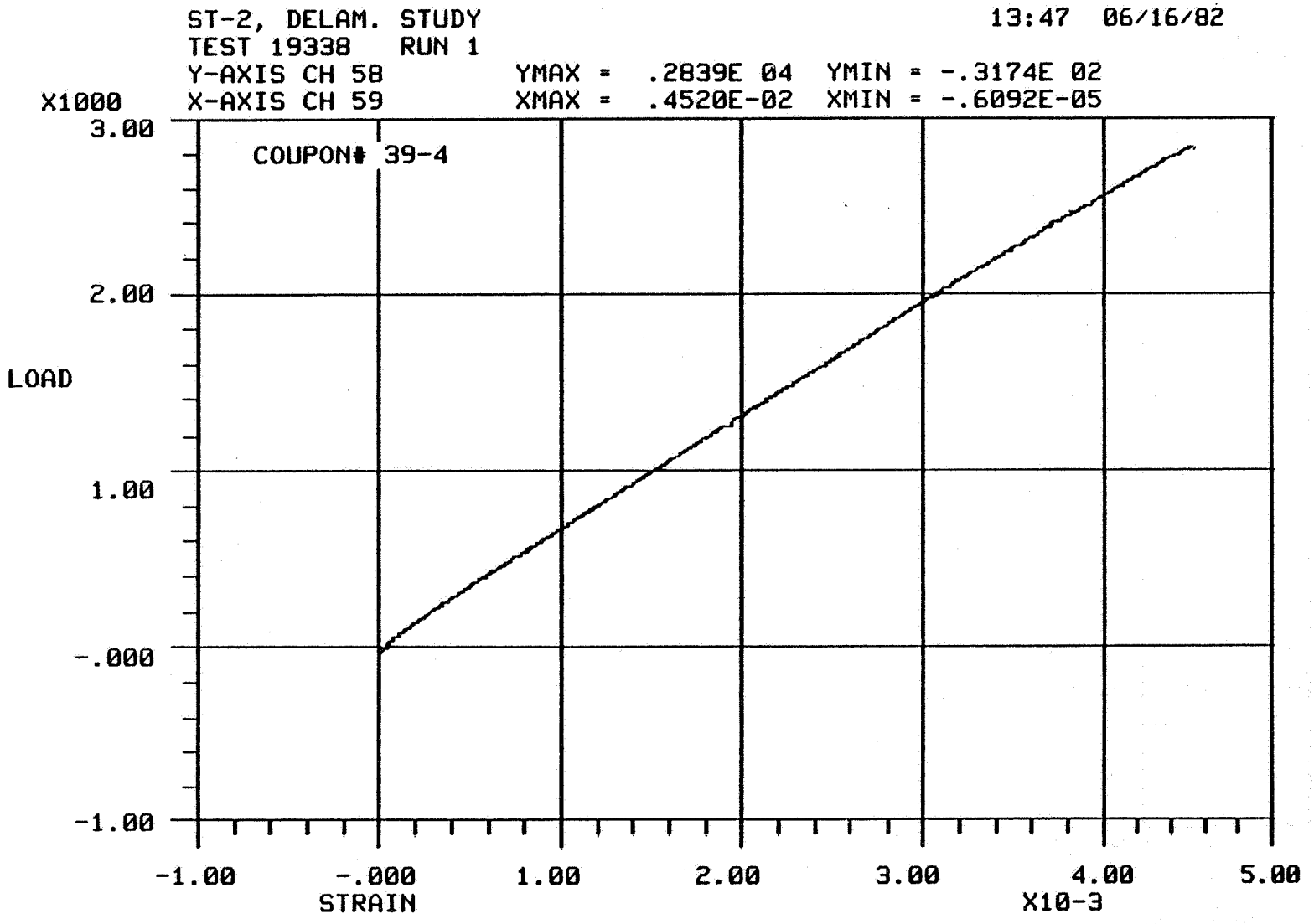

ST-2, DELAM. STUDY
15:14 06/15/82
TEST 19320 RUN 2
Y-AXIS CH 58
YMAX = .2156E 04
YMIN = -.1281E 02
X1000
X-AXIS CH 59
XMAX = .3186E-02
XMIN = .1831E-04
COUPON# 19-4
2.50
2.00
1.50
LOAD
1.00
.500
-.000
-.500
0.
.500
1.00
1.50
2.00
2.50
3.00
3.50
STRAIN
X10-3

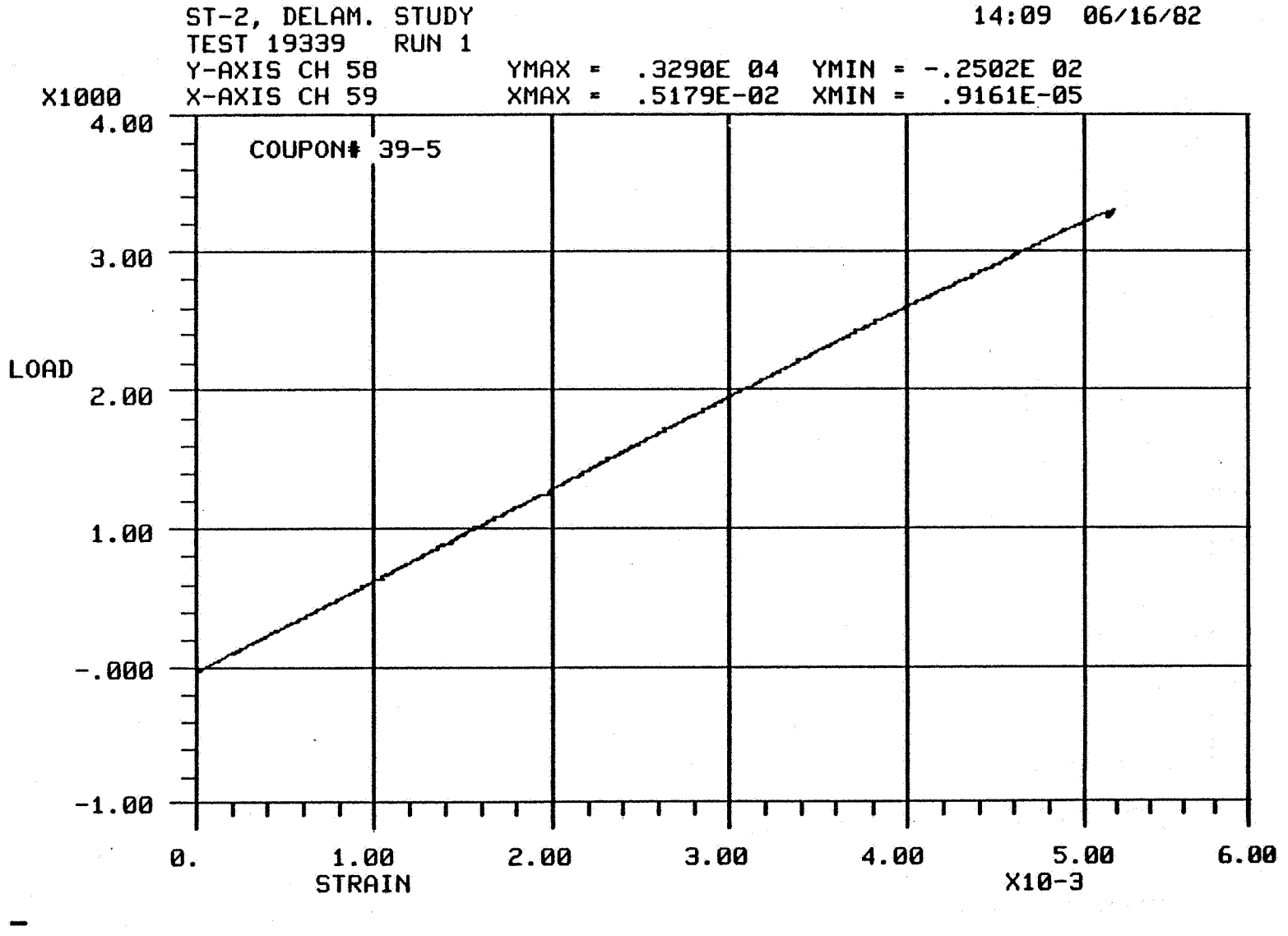

ST-2, DELAM. STUDY
08:23 06/16/82
TEST 19326 RUN 1
Y-AXIS CH 58 YMAX = .2067E 04 YMIN = -.3540E 02
X1000 X-AXIS CH 59 XMAX = .3058E-02 XMIN = -.3659E-04
COUPON# 19-5
2.50
2.00
1.50
LOAD
1.00
.500
-.000
-.500
-.500 -.000 .500 1.00 1.50 2.00 2.50 3.00 3.50
STRAIN
X10-3


ST-2, DELAM. STUDY
09:15 06/16/82
TEST 19329 RUN 1
Y-AXIS CH 58 YMAX = .2902E 04 YMIN = -.3172E 02
X1000 X-AXIS CH 59 XMAX = .4669E-02 XMIN = -.6104E-05
COUPON# 39-1
3.00
2.00
1.00
-.000
-1.00
LOAD
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
STRAIN
X10-3


ST-2, DELAM. STUDY
11:33 06/16/82
TEST 19334 RUN 2
Y-AXIS CH 58
YMAX = .3218E 04
YMIN = -.2990E 02
X-AXIS CH 59
XMAX = .5319E-02
XMIN = -.3035E-05
X1000
COUPON# 39-2
LOAD
4.00
3.00
2.00
1.00
-.000
-1.00
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
6.00
STRAIN
X10-3


ST-2, DELAM. STUDY
13:13 06/16/82
TEST 19337 RUN 1
Y-AXIS CH 58
YMAX = .3235E 04
YMIN = -.3357E 02
X1000
X-AXIS CH 59
XMAX = .5063E-02
XMIN = -.1220E-04
COUPON# 39-3
LOAD
4.00
3.00
2.00
1.00
-.000
-1.00
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
6.00
STRAIN
X10-3


ST-2, DELAM. STUDY
13:47 06/16/82
TEST 19338 RUN 1
Y-AXIS CH 58 YMAX = .2839E 04 YMIN = -.3174E 02
X1000 X-AXIS CH 59 XMAX = .4520E-02 XMIN = -.6092E-05
COUPON# 39-4
3.00
2.00
1.00
-.000
-1.00
LOAD
-1.00
-.000
1.00
2.00
3.00
4.00
5.00
STRAIN
X10-3


ST-2, DELAM. STUDY
14:09 06/16/82
TEST 19339 RUN 1
Y-AXIS CH 58
YMAX = .3290E 04 YMIN = -.2502E 02
X-AXIS CH 59
XMAX = .5179E-02 XMIN = .9161E-05
X1000
COUPON# 39-5
4.00
3.00
2.00
1.00
-.000
-1.00
LOAD
0.
1.00
2.00
3.00
4.00
5.00
6.00
STRAIN
X10-3

APPENDIX B9

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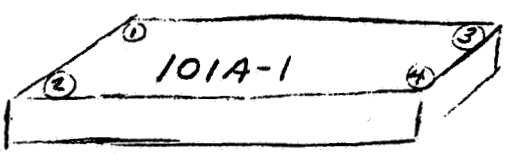
PAUL SANDIFER 10/14/82
C.W. LOOPER

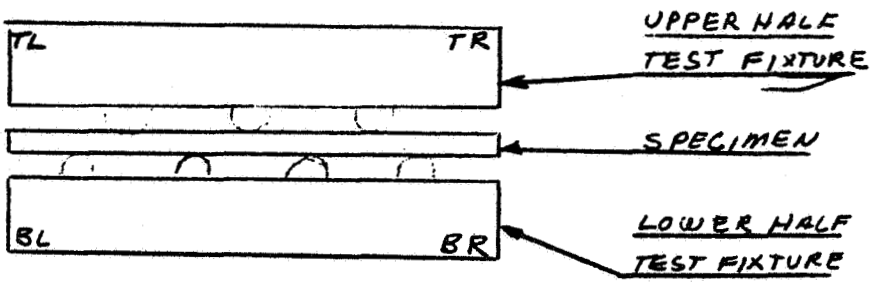
7-PIN SHEAR TEST
101A-1 → 101A-6 SUMMARY

DIMENSIONS FOR SPECIMENS 101A-1 thru. 101A-6 ARE ON EM 11544-44 AND -45

FOR FAILURE PATTERN SEE EM 11544-46

SPECIMENS WERE TESTED WITH COUPON NUMBER UP AND DASH NUMBER TO RIGHT
EXAMPLE:





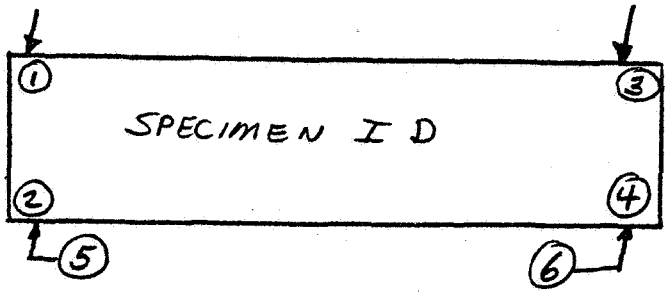
NOTE: TL = TOP LEFT, BR = BOTTOM RIGHT ··· ETC

SPECIMENS 101A-1 thru 101A-5 WERE TESTED USING ORIENTATION SHOWEN ABOVE. 101A-6 THE UPPER HALF OF THE TEST FIXTURE WAS REVERSED SO THE TOP RIGHT END BECAME THE TOP LEFT END.

COUPON ID	DATA CENTRAL TEST NO.	RUN NO	MAX LOAD-LBS	DEFLECTION IN.
101A-1	20494	1	-7751	-.083
101A-2	20498	1	-7051	-.080
101A-3	20498	2	-6909	-.078
101A-4	20498	3	-8751	-.093
101A-5	20498	4	-7881	-.086
101A-6	20498	5	-9040	-.096

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		7 PIN SHEAR DIMENSIONS	

MEASUREMENT PATTERN.



SPECIMEN NO. 101A-1

POSITION		
1	.2413	
2	.2391	
3	.2521	AVE. = .2460
4	.2517	
5	.9979	AVE = 1.0000
6	1.0022	

SPECIMEN NO. 101A-2

1	.2375	
2	.2336	AVE = .2406
3	.2480	
4	.2432	
5	1.0023	AVE = 1.0012
6	1.0002	

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ENGINEERS NOTEBOOK

№ 11544-45

7 PIN SHEAR

~~DIMENSIONS~~

-44

SPECIMEN NO. 101A-3

①	.2560	AVE. = .2572
②	.2546	
③	.2610	
④	.2570	
⑤	1.0022	AVE 1.0023
⑥	1.0024	

SPECIMEN NO. 101A-4

①	~~.2575~~ .2517	AVE .2517
②	.2497	
③	.2551	
④	.2504	
⑤	1.0025	AVE - 1.0022
⑥	1.0018	

SPECIMEN NO. 101A-5

①	.2606	AVE .2587
②	.2574	
③	.2602	
④	.2566	
⑤	1.0017	AVE 1.0018
⑥	1.0019	

SPECIMEN NO. 101A-6

①	.2554	AVE .2533
②	.2522	
③	.2544	
④	.2511	
⑤	1.0015	AVE 1.0020
⑥	1.0024	

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C. LOOPER

LOCKHEED CALIFORNIA COMPANY
ENGINEERS NOTEBOOK

№ 11544-47

5 PIN SHEAR

USING SAME MEASUREMENT PATTERN AS EN - 44

SPECIMEN NO. 101A-8

Position		
1	.2535	.2500
2	.2496	
3	.2500	
4	.2469	
5	1.0022	ave 1.0020
6	1.0017	

SPECIMEN NO. 101A-9

1	.2463	.2417
2	.2381	
3	.2443	
4	.2381	
5	1.0049	1.0042
6	1.0036	

SPECIMEN NO. 101A-10

1	.2551	.2518
2	.2502	
3	.2526	
4	.2493	
5	1.0003	1.0002
6	1.0000	

SPECIMEN NO. 101A-11

1	.2578	.2573
2	.2547	
3	.2608	
4	.2560	
5	1.0039	1.0041
6	1.0044	

SPECIMEN NO. 101A-12

1	.2521	.2510
2	.2481	
3	.2537	
4	.2501	
5	.9994	.9999
6	1.0003	

SPECIMEN NO. 101A-13

1	.2593	.2580
2	.2550	
3	.2608	
5	1.0070	1.0052
6	1.0033	
4	.2568	

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ENGINEERS NOTEBOOK

№ 11544-42

7-PIN SHEAR

SEE EN-46 FOR FAILURE MODE

SPECIMEN NO. 101A-1 ~~LOAD RATE~~
DATA CENTRAL TEST. NO. 20494 RUN NO. 1
MAX LOAD -7751 LB DEFLECTION -.083
AREA .2468 x 1.000 = .2468 IN^2

SPECIMEN NO 101A-2 ~~LOAD RATE~~
DATA CENTRAL TEST NO. 20498 RUN NO 1
MAX LOAD -7051 LB DEFLECTION -.080
AREA = .2407 x 1.0014 = .2410 IN^2

SPECIMEN NO. 101A-3 ~~LOAD RATE~~
DATA CENTRAL TEST NO 20498 RUN NO. 2
MAX LOAD -6909 DEFLECTION -.078
AREA = .2574 x 1.0015 = .2578 IN^2

SPECIMEN NO. 101A-4 ~~LOAD RATE~~
DATA CENTRAL TEST NO 20498 RUN NO 3
MAX LOAD -8751 LB DEFLECTION -.093
AREA = .2531 x 1.0020 = .2536 IN^2

SPECIMEN NO. 101A-5 ~~LOAD~~ ~~RATE~~
DATA CENTRAL TEST NO. 20498 RUN NO 4
MAX LOAD -7881 DEFLECTION -.086
AREA = .2573 x 1.0014 = .2577 IN^2

SPECIMEN NO. 101A-6 ~~LOAD RATE~~
DATA CENTRAL TEST NO 20498 RUN NO 5
MAX LOAD -9040 LB DEFLECTION -.096
AREA = .2525 x 1.0017 = .2529 IN^2

SPECIMEN NO 101A-7 LOAD RATE
DATA CENTRAL TEST NO RUN NO.
MAX LOAD DEFLECTION
AREA = .2567 x 1.0015 = .2571 IN^2

NOTE: LOAD RATE IS .05"/MIN

NOTE: TEST SUMMARY EN 11544-50

NOTE: -1 thru -5, TL/BL . -6 TR/BL

P. SANDIFER C. LOOPER	10/15/82	ENGINEERS NOTEBOOK 5 PIN SHEAR	Nº 11544-49

DIMENSIONS OF COUPONS ON EM 11544-47
DATA CENTRAL TEST NO. 20502
SPECIMEN NO. 101A-8
MAX LOAD. -5266 LB, DEFLECTION -.068
RUN # 1

SPECIMEN NO. 101A-9
MAX LOAD -4817 LB, DEFL. -.063
RUN #2

SPECIMEN NO. 101A-10
MAX LOAD -4893 LB. DEFL. -.061
RUN #3

SPECIMEN NO. 101A-11
MAX LOAD -5260. DEFL. -.064
RUN #4

SPECIMEN NO. 101A-12
MAX LOAD -4895 LB DEFL. -.060
RUN #5

SPECIMEN NO. 101A-13
MAX. LOAD -5351 LB DEFL. -.070
RUN #6

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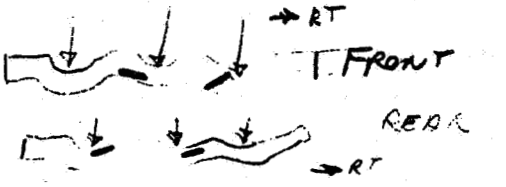
P. SANDIFER
C. COOPER

ENGINEERS NOTEBOOK

№ 11544-46

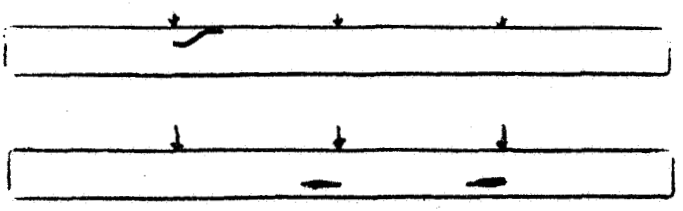
7 PIN SHEAR FAILURE PATTERN

101A-1



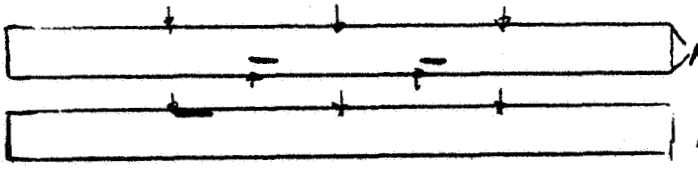
TR (TOP RT) / BL (BOTT LEFT)

101A-2



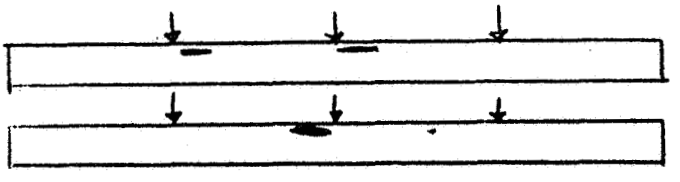
TR / BR

101A-3



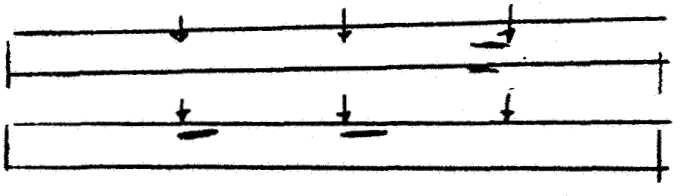
TR / BL ← photo

101A-4



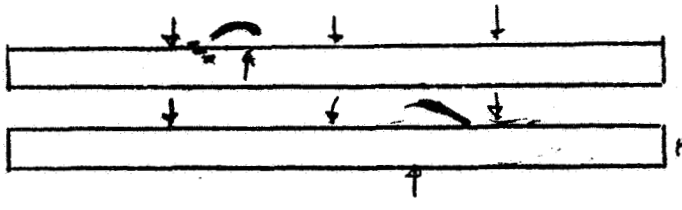
TR / BR ← photo

101A-5



TR / BL

101A-6

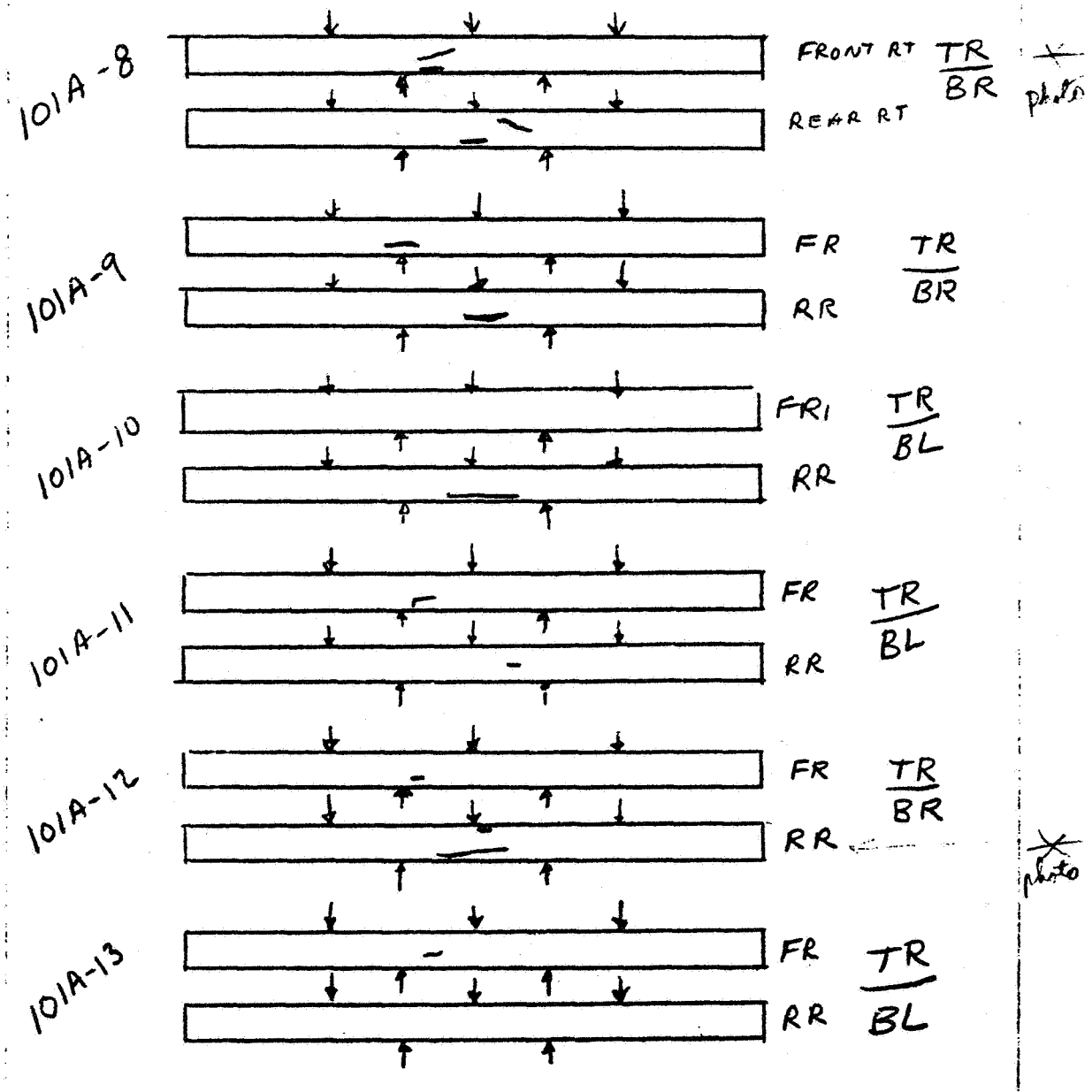


TR / BR ← photo

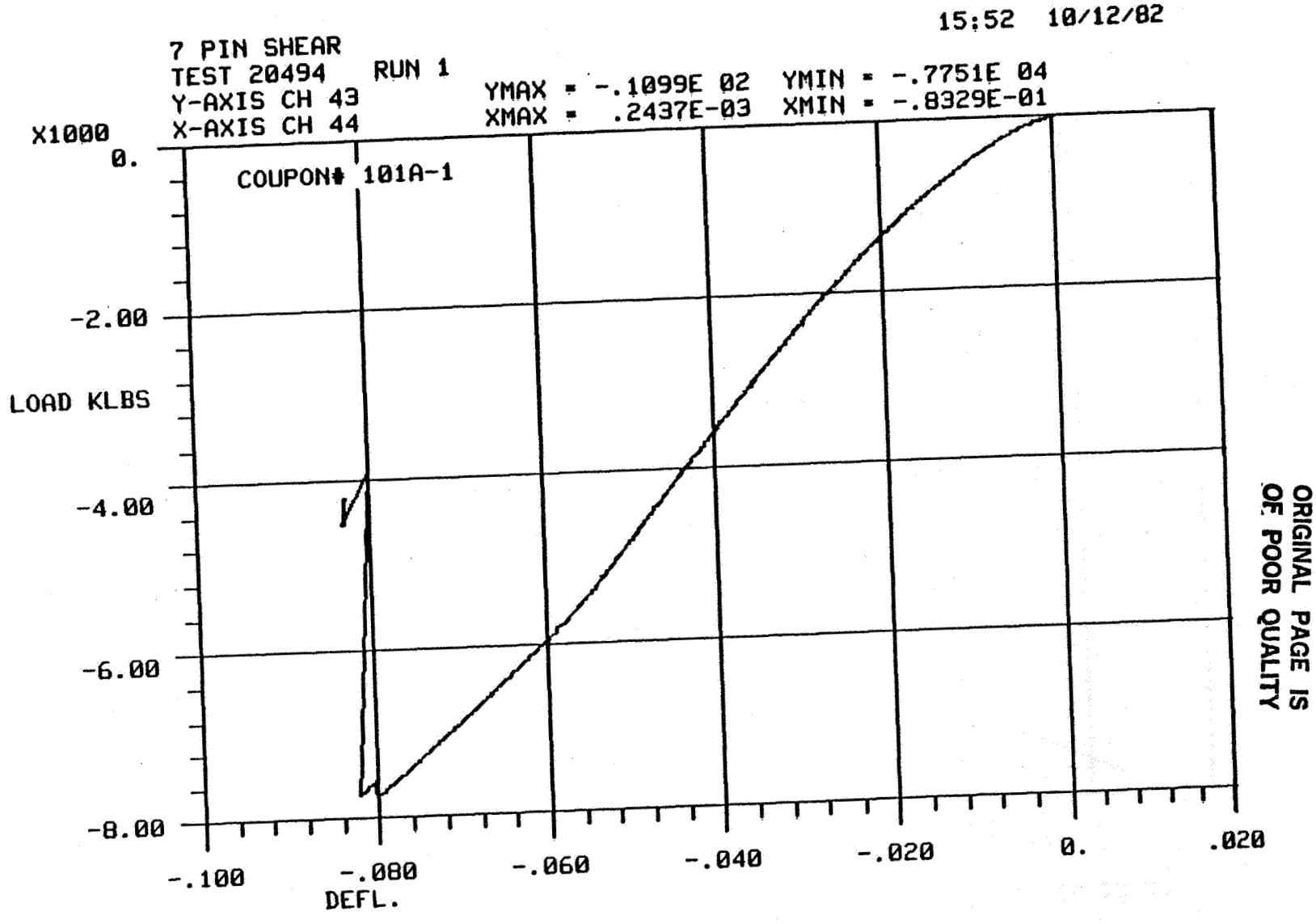
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P. SANDIFER 10/13/82 ENGINEERS NOTEBOOK № 11544-48
C. LOOPER

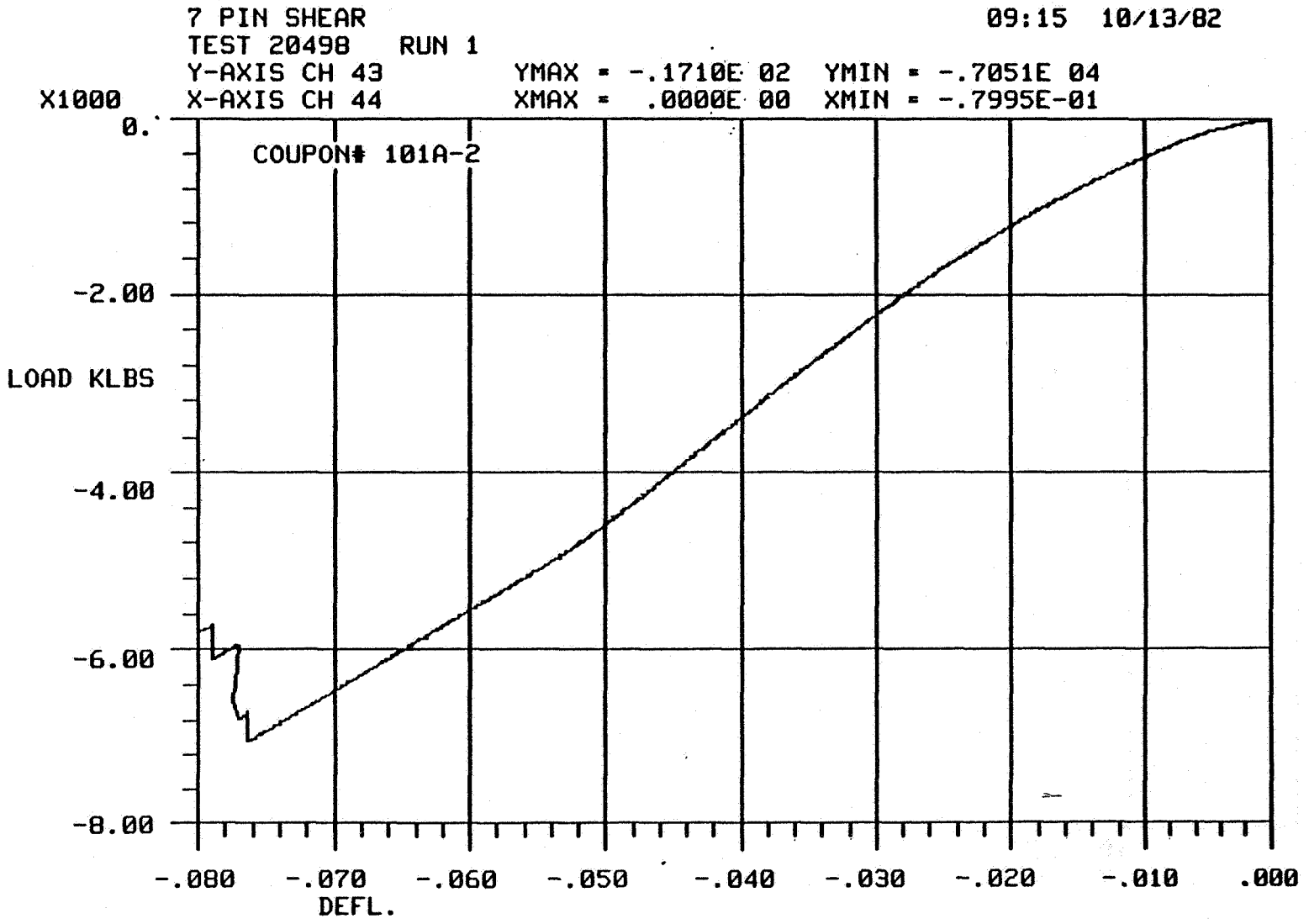
5 PIN SHEAR

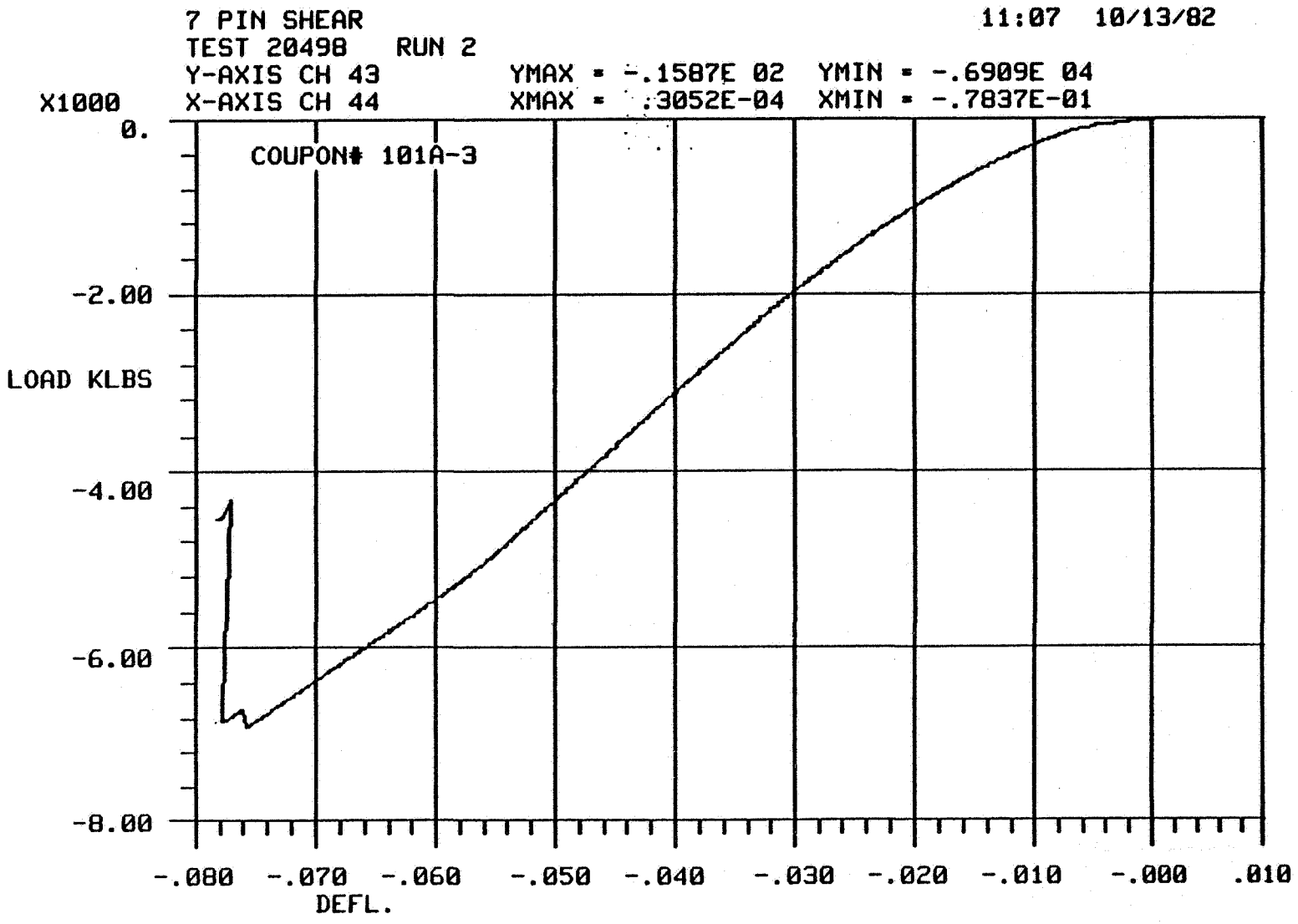


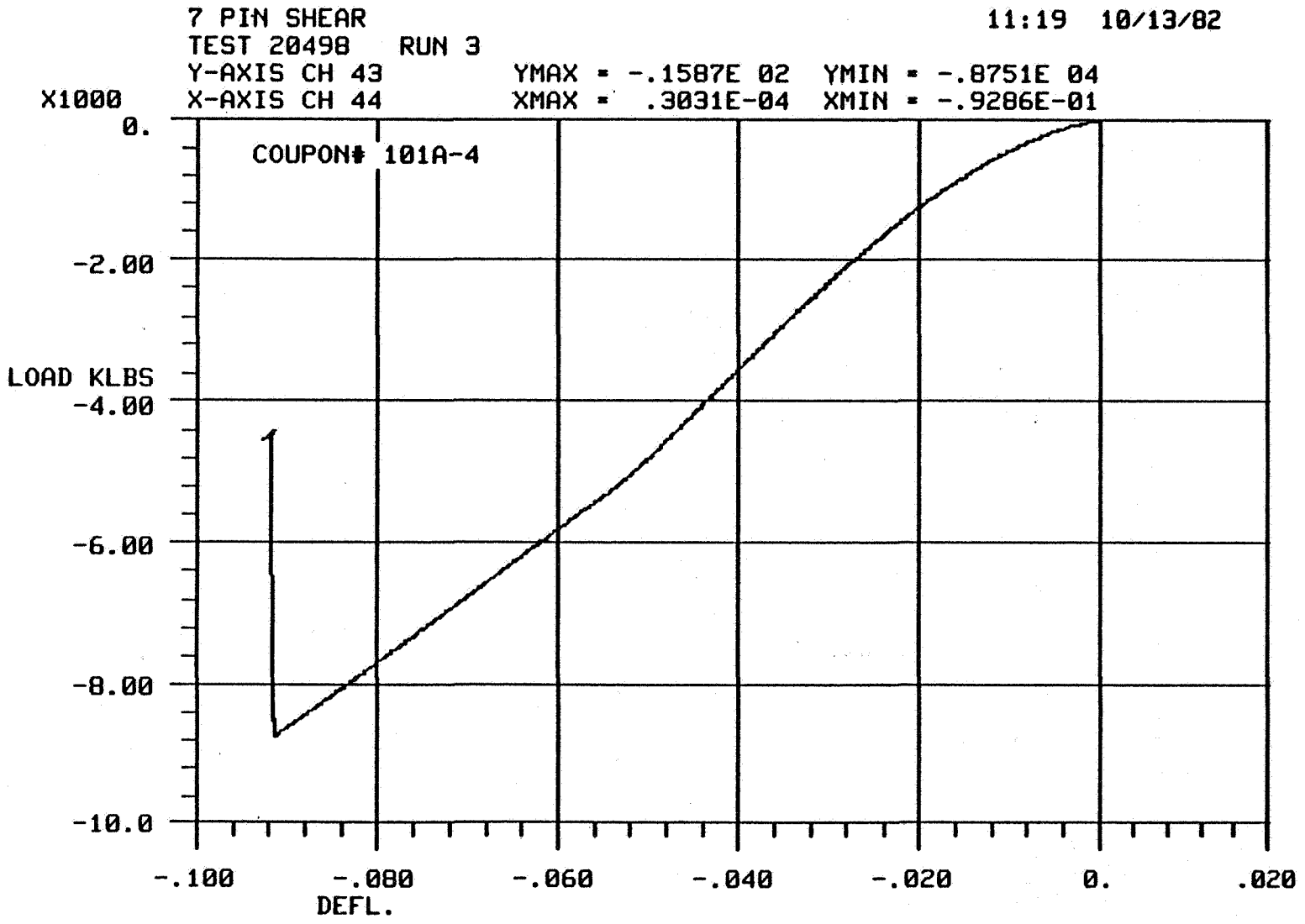
NOTE: TR = TOP RIGHT, BR = BOTTOM RIGHT AND BL = BOTTOM LEFT. THE UPPER (3 PIN BAR) WAS ONLY ONE ROTATED

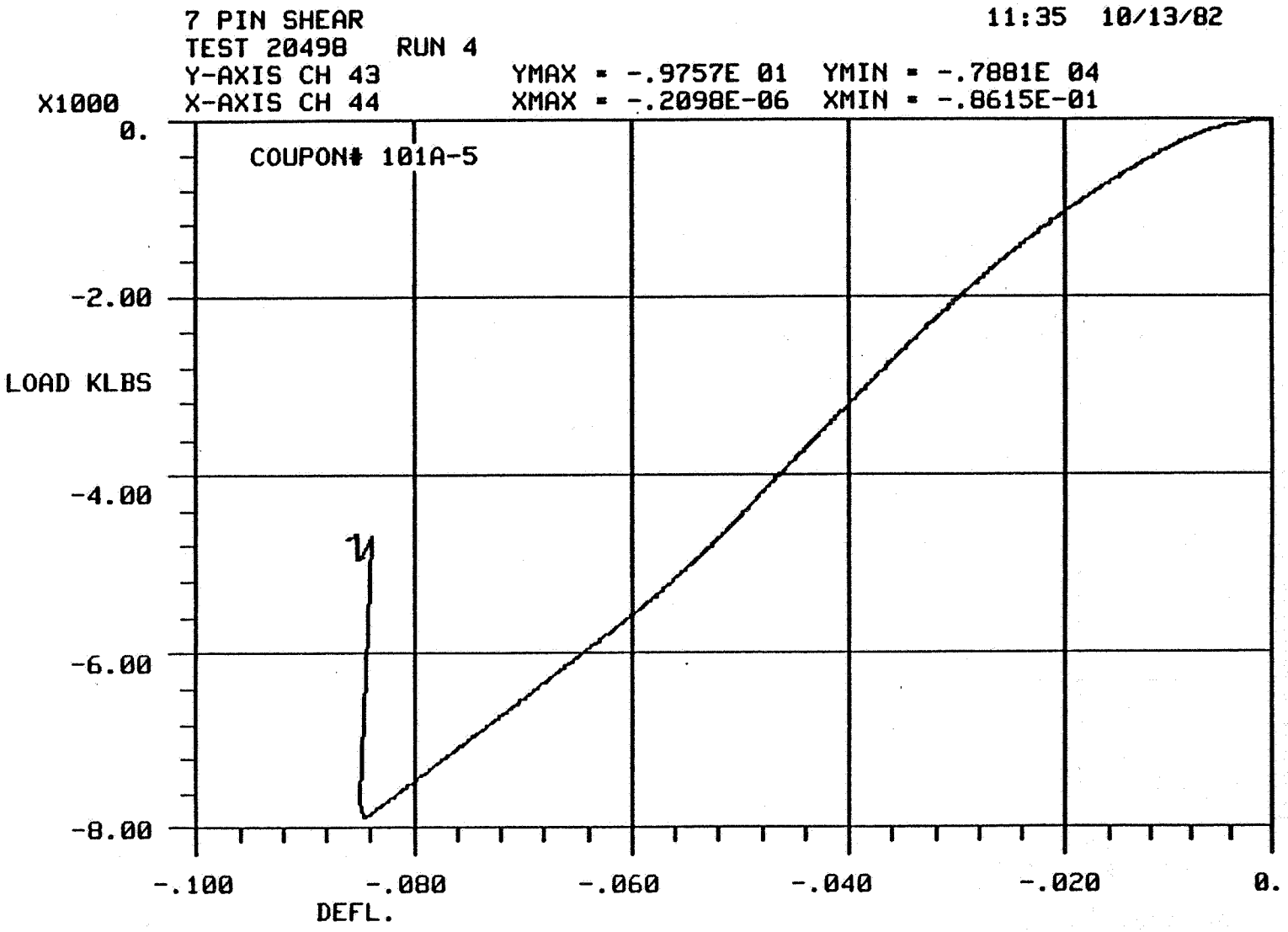


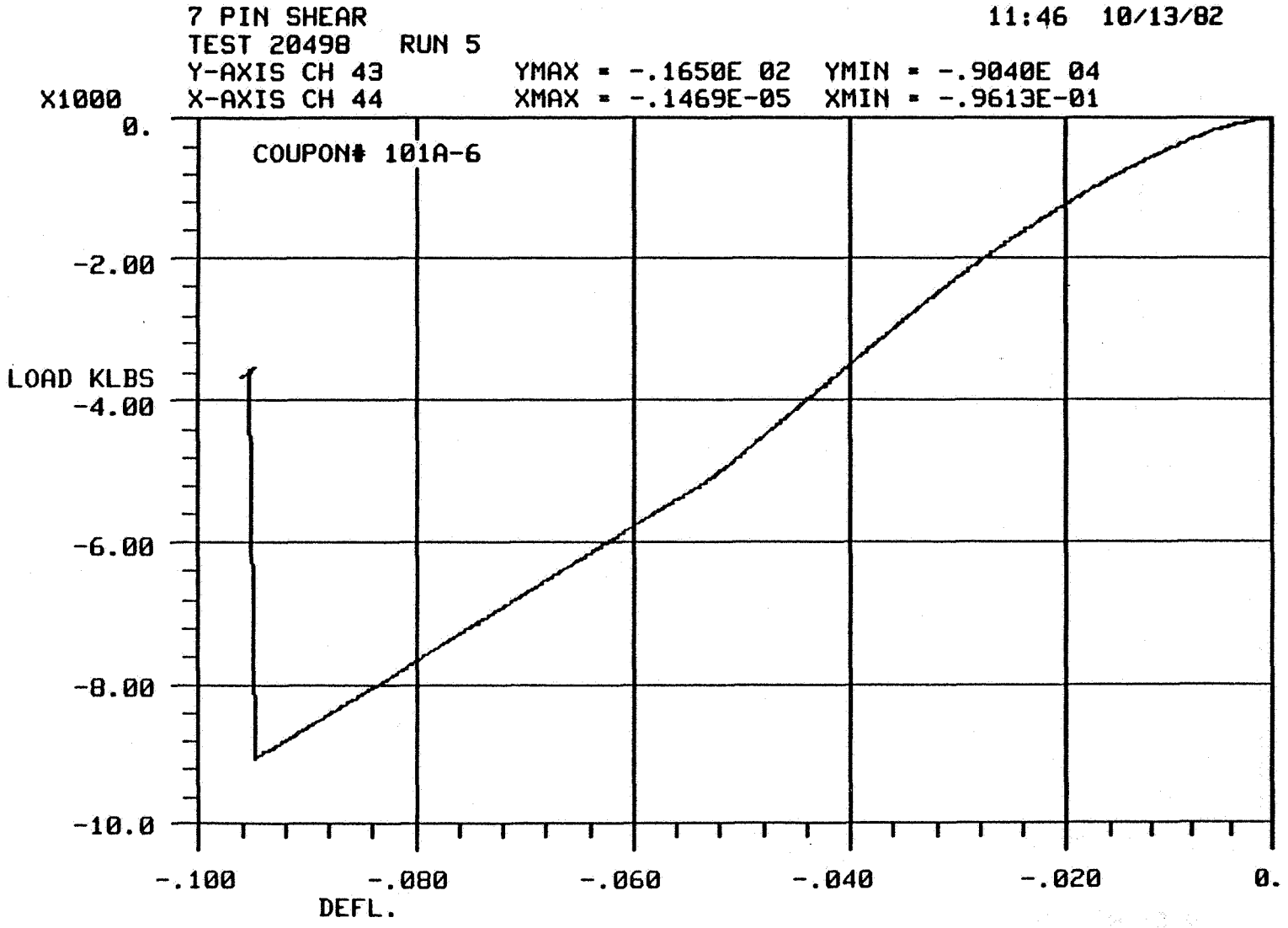
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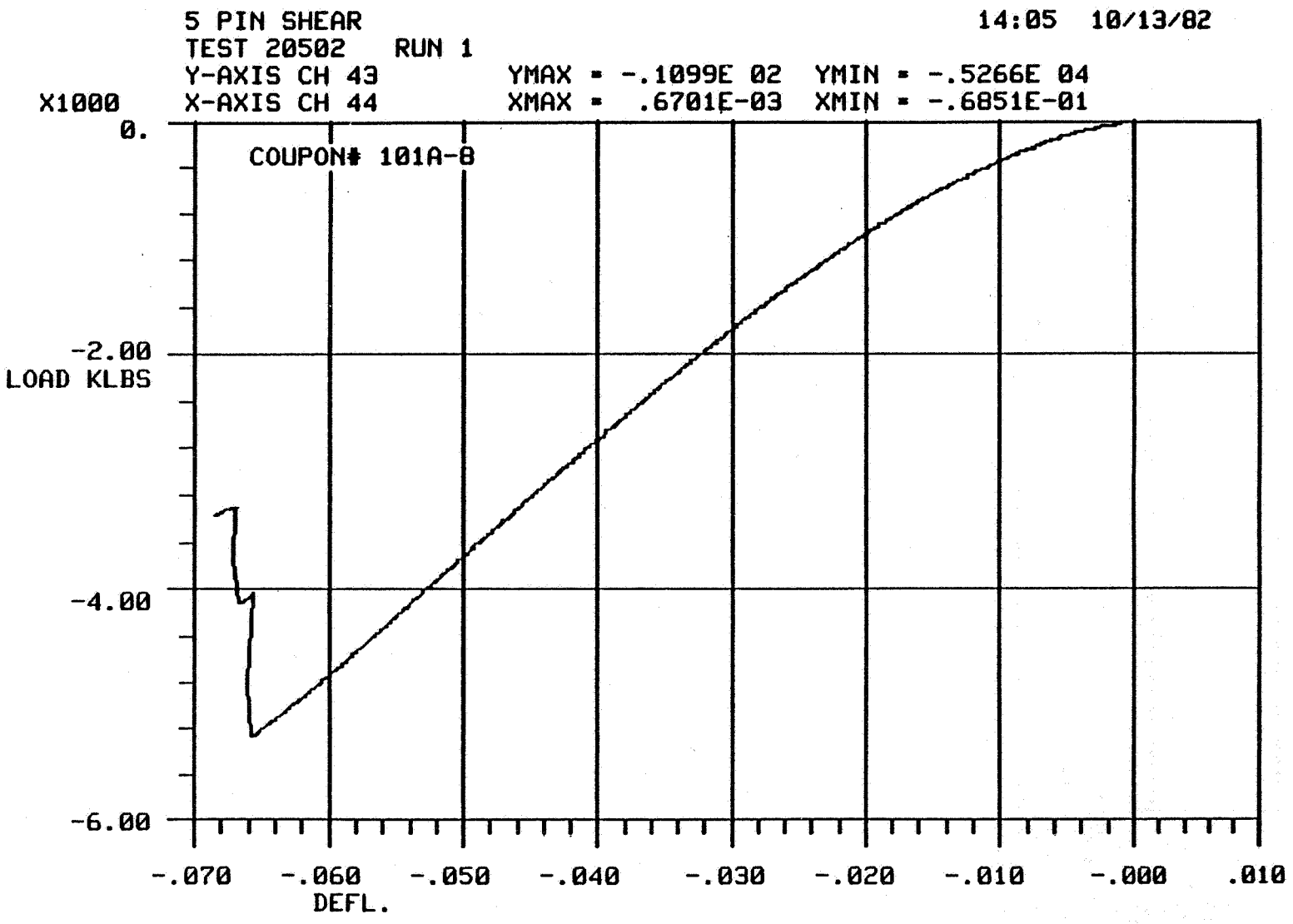

7 PIN SHEAR
09:15 10/13/82
TEST 20498 RUN 1
Y-AXIS CH 43
YMAX = -.1710E 02 YMIN = -.7051E 04
X1000
X-AXIS CH 44
XMAX = .0000E 00 XMIN = -.7995E-01
0.
COUPON# 101A-2
-2.00
LOAD KLBS
-4.00
-6.00
-8.00
-.080 -.070 -.060 -.050 -.040 -.030 -.020 -.010 .000
DEFL.

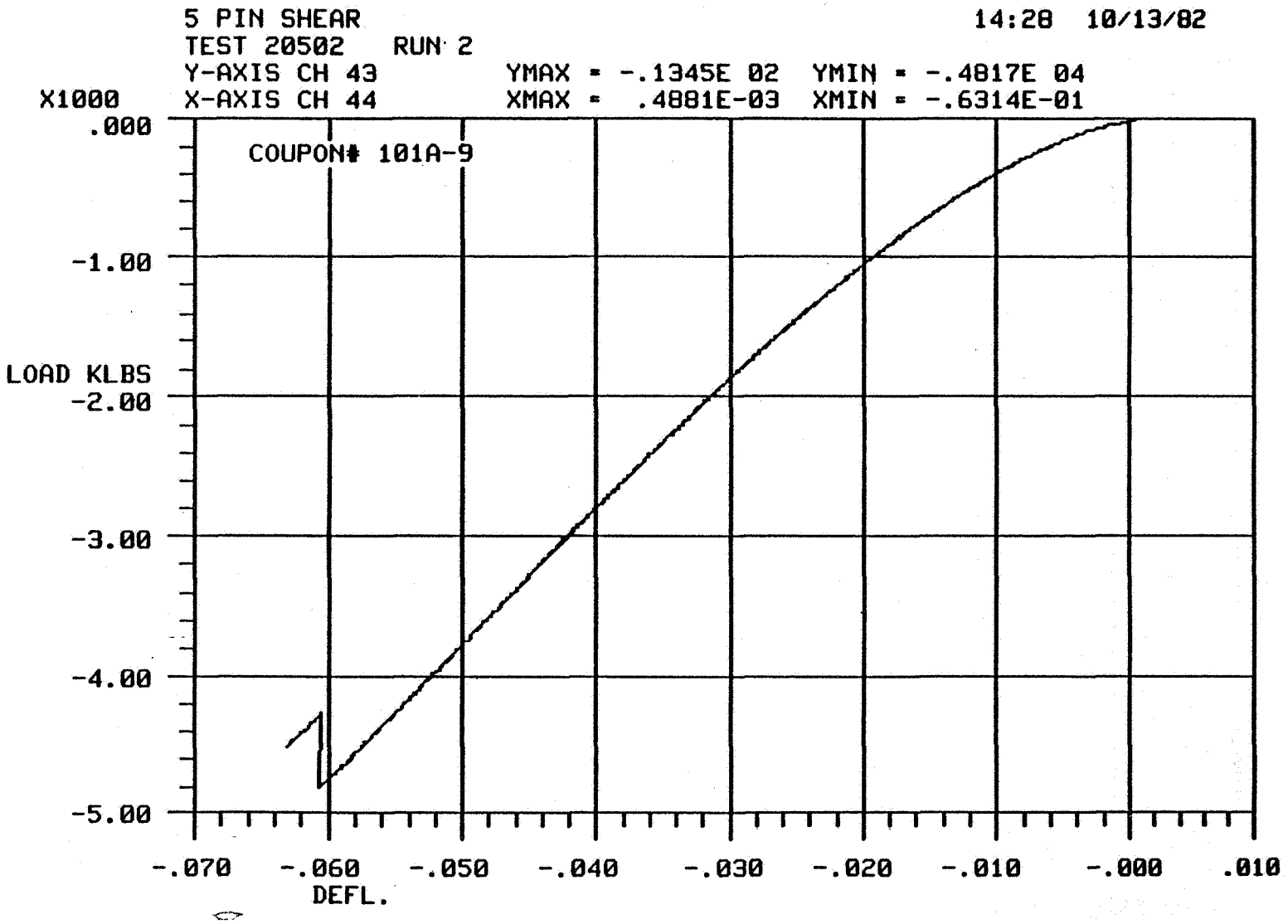

7 PIN SHEAR
11:07 10/13/82
TEST 20498 RUN 2
Y-AXIS CH 43
YMAX = -.1587E 02
YMIN = -.6909E 04
X1000
X-AXIS CH 44
XMAX = .3052E-04
XMIN = -.7837E-01
0.
COUPON# 101A-3
-2.00
LOAD KLBS
-4.00
-6.00
-8.00
-.080
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
.010
DEFL.

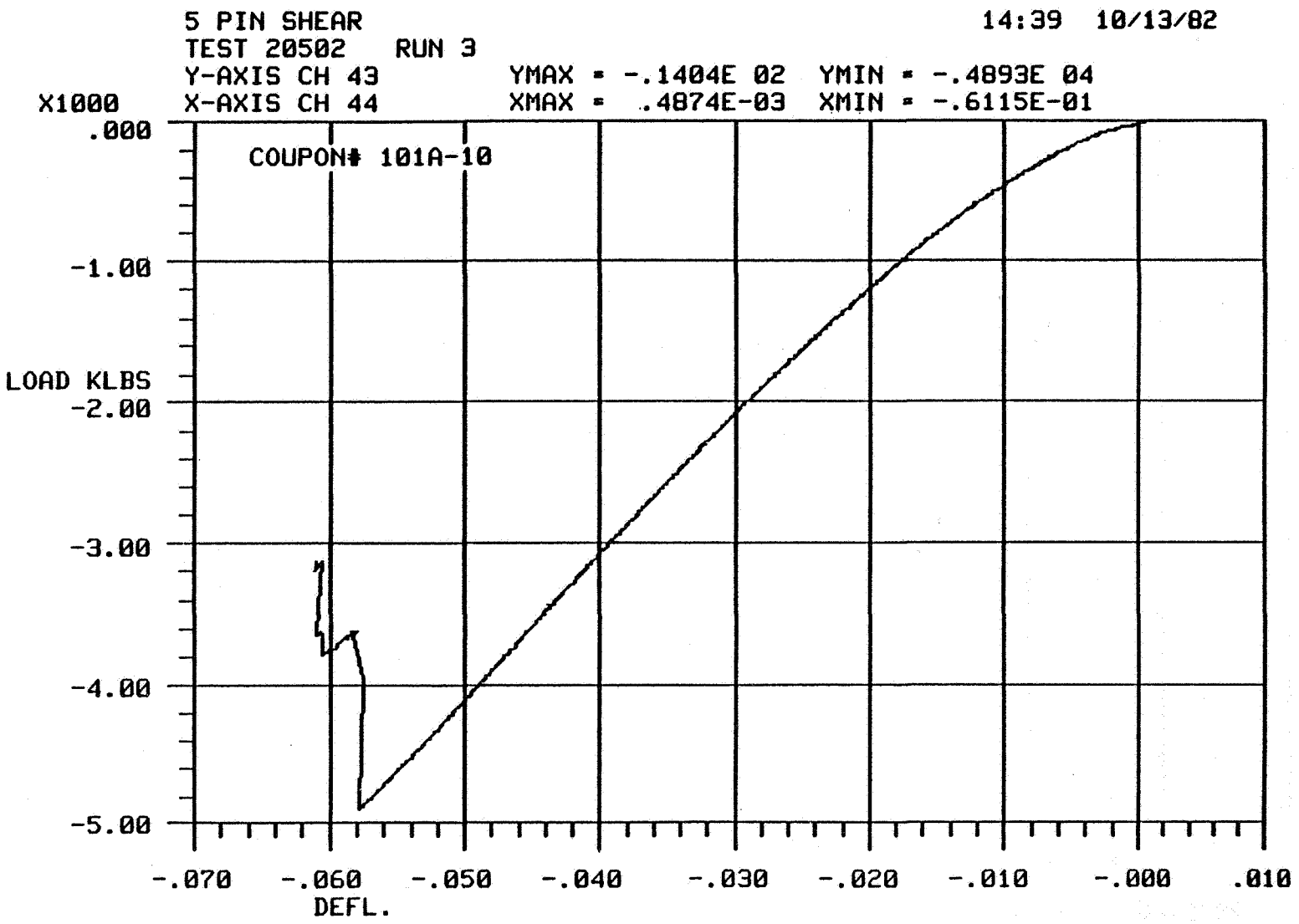

7 PIN SHEAR
11:19 10/13/82
TEST 20498 RUN 3
Y-AXIS CH 43
YMAX = -.1587E 02 YMIN = -.8751E 04
X1000
X-AXIS CH 44
XMAX = .3031E-04 XMIN = -.9286E-01
0.
COUPON# 101A-4
-2.00
LOAD KLBS
-4.00
-6.00
-8.00
-10.0
-.100
-.080
-.060
-.040
-.020
0.
.020
DEFL.

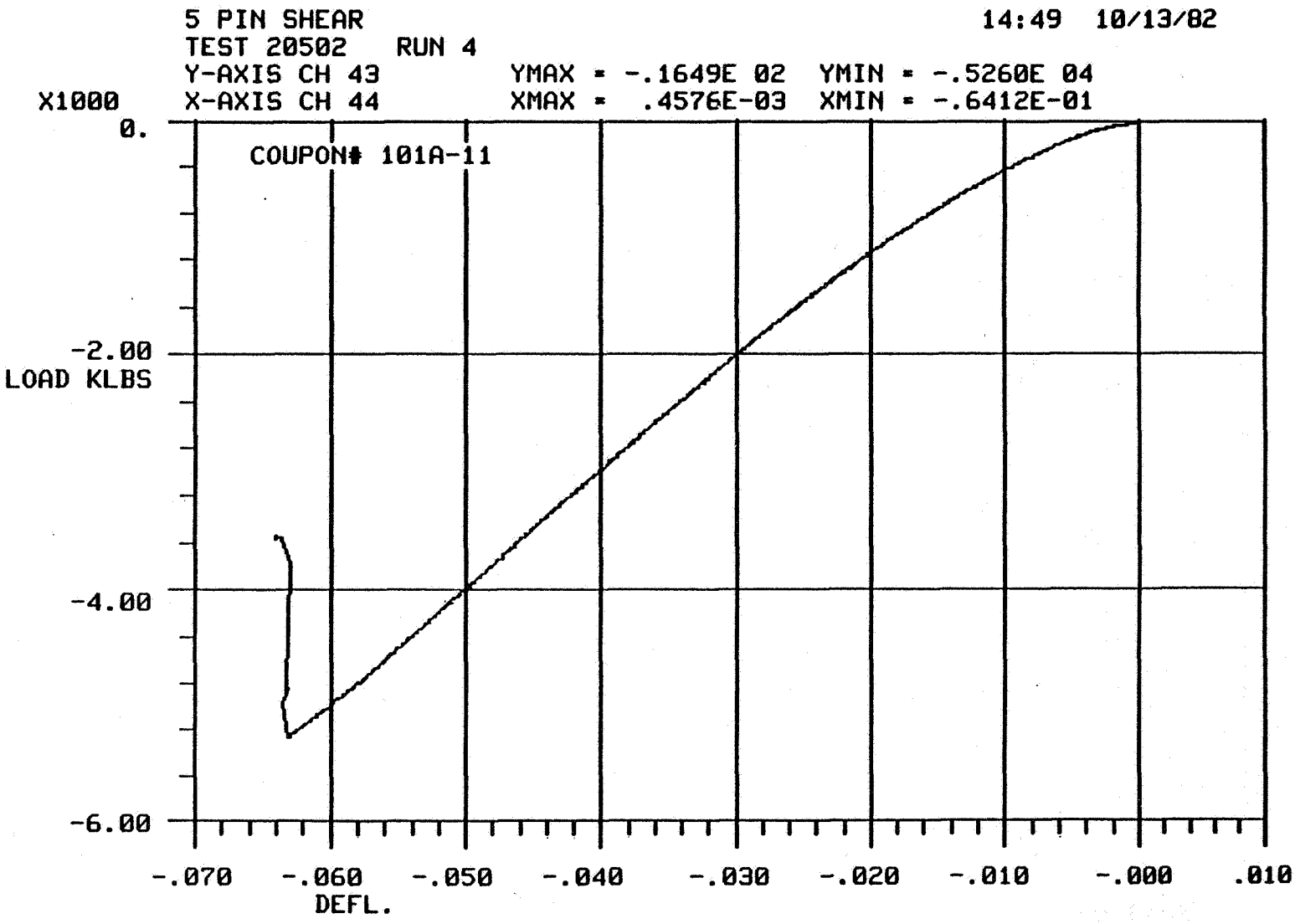

7 PIN SHEAR
11:35 10/13/82
TEST 20498 RUN 4
Y-AXIS CH 43
YMAX = -.9757E 01 YMIN = -.7881E 04
X-AXIS CH 44
XMAX = -.2098E-06 XMIN = -.8615E-01
X1000
0.
COUPON# 101A-5
-2.00
LOAD KLBS
-4.00
-6.00
-8.00
-.100
-.080
-.060
-.040
-.020
0.
DEFL.

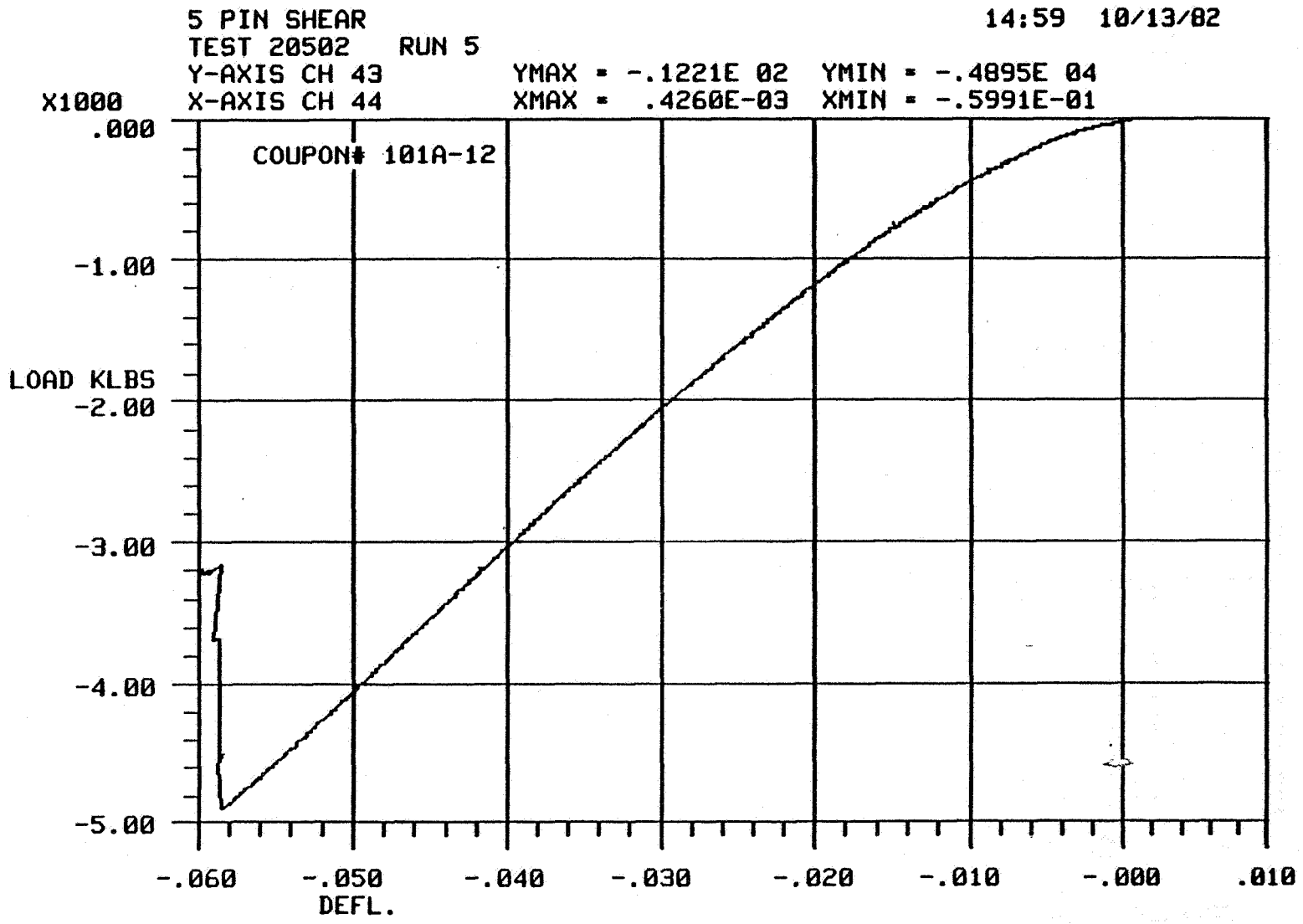

7 PIN SHEAR
11:46 10/13/82
TEST 20498 RUN 5
Y-AXIS CH 43
YMAX = -.1650E 02
YMIN = -.9040E 04
X1000
X-AXIS CH 44
XMAX = -.1469E-05
XMIN = -.9613E-01
0.
COUPON# 101A-6
-2.00
LOAD KLBS
-4.00
-6.00
-8.00
-10.0
-.100
-.080
-.060
-.040
-.020
0.
DEFL.

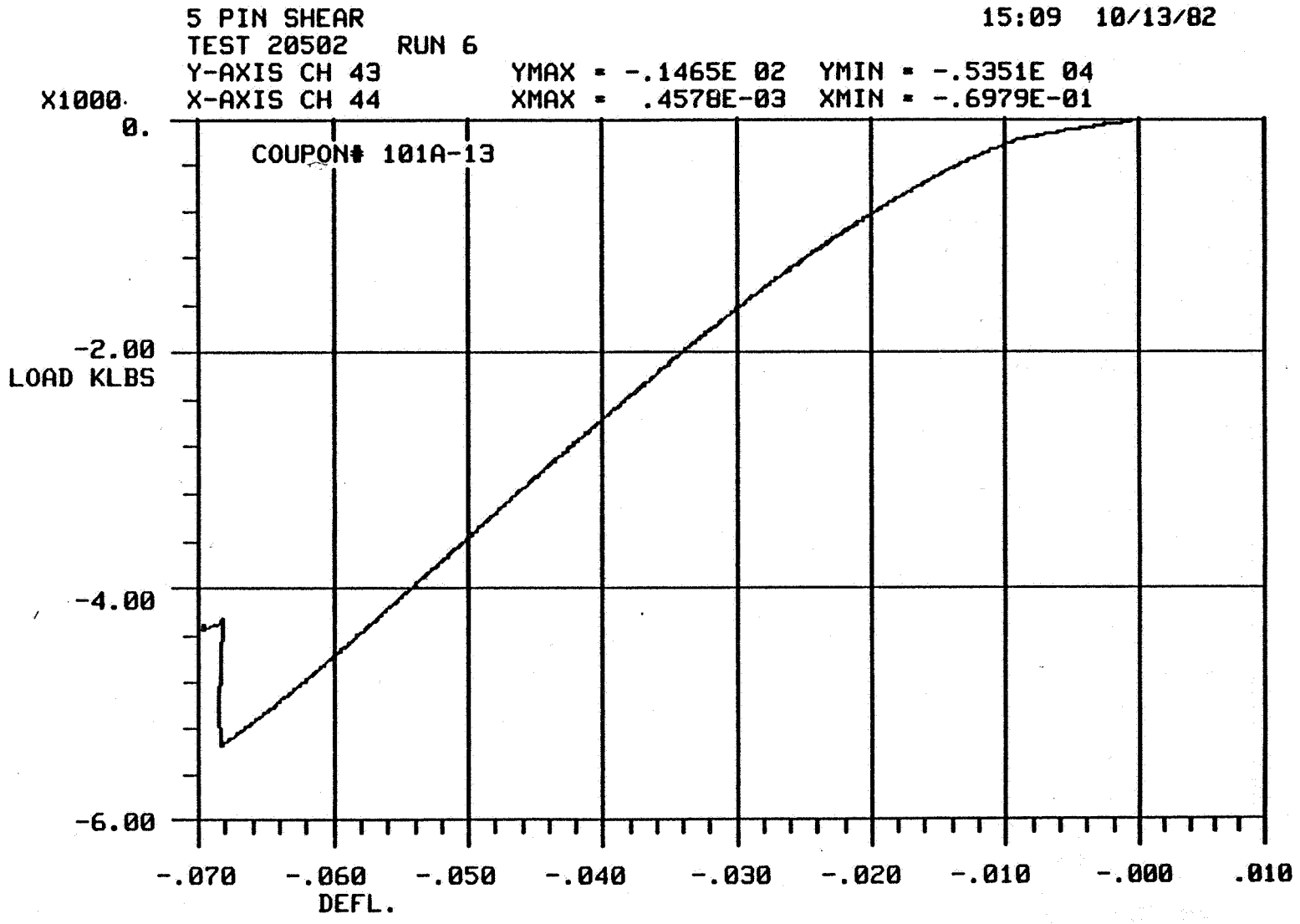

5 PIN SHEAR
14:05 10/13/82
TEST 20502 RUN 1
Y-AXIS CH 43 YMAX = -.1099E 02 YMIN = -.5266E 04
X1000 X-AXIS CH 44 XMAX = .6701E-03 XMIN = -.6851E-01
0.
COUPON# 101A-8
-2.00
LOAD KLBS
-4.00
-6.00
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
.010
DEFL.


5 PIN SHEAR
14:28 10/13/82
TEST 20502 RUN 2
Y-AXIS CH 43
YMAX = -.1345E 02
YMIN = -.4817E 04
X1000
X-AXIS CH 44
XMAX = .4881E-03
XMIN = -.6314E-01
.000
COUPON# 101A-9
-1.00
LOAD KLBS
-2.00
-3.00
-4.00
-5.00
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
.010
DEFL.


5 PIN SHEAR
14:39 10/13/82
TEST 20502 RUN 3
Y-AXIS CH 43
YMAX = -.1404E 02 YMIN = -.4893E 04
X1000
X-AXIS CH 44
XMAX = .4874E-03 XMIN = -.6115E-01
.000
COUPON# 101A-10
-1.00
LOAD KLBS
-2.00
-3.00
-4.00
-5.00
-.070 -.060 -.050 -.040 -.030 -.020 -.010 -.000 .010
DEFL.


5 PIN SHEAR
14:49 10/13/82
TEST 20502 RUN 4
Y-AXIS CH 43
YMAX = -.1649E 02
YMIN = -.5260E 04
X1000
X-AXIS CH 44
XMAX = .4576E-03
XMIN = -.6412E-01
0.
COUPON# 101A-11
-2.00
LOAD KLBS
-4.00
-6.00
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
.010
DEFL.


5 PIN SHEAR
14:59 10/13/82
TEST 20502 RUN 5
Y-AXIS CH 43
YMAX = -.1221E 02
YMIN = -.4895E 04
X1000
X-AXIS CH 44
XMAX = .4260E-03
XMIN = -.5991E-01
.000
COUPON# 101A-12
-1.00
LOAD KLBS
-2.00
-3.00
-4.00
-5.00
-.060
-.050
-.040
-.030
-.020
-.010
-.000
.010
DEFL.


5 PIN SHEAR
15:09 10/13/82
TEST 20502 RUN 6
Y-AXIS CH 43 YMAX = -.1465E 02 YMIN = -.5351E 04
X1000 X-AXIS CH 44 XMAX = .4578E-03 XMIN = -.6979E-01
0.
COUPON# 101A-13
-2.00
LOAD KLBS
-4.00
-6.00
-.070 -.060 -.050 -.040 -.030 -.020 -.010 -.000 .010
DEFL.

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Nº 11544-41

7 PIN SHEAR

SPECIMEN NO. 15-7-1
DATA CENTRAL TEST NO 20489
MAX LOAD -4668 LBS
AREA = 1.0013 x .2644 = .2647 in²
LOAD RATE .05"/MIN
RUN NO. 1
DEFLECTION -.060

SPECIMEN NO. 15-7-2
DATA CENTRAL TEST NO. 20489
MAX LOAD -5649 LB
AREA = 1.0050 x .2643 = .2656 in²
LOAD RATE .05"/MIN
RUN NO. 2
DEFLECTION -.063

SPECIMEN NO. 15-7-3
DATA CENTRAL TEST NO. 20489
MAX LOAD -5209 LB
AREA = 1.0076 x .2650 = .2670 in²
LOAD RATE .05"/MIN
RUN NO. 3
DEFLECTION -.059

SPECIMEN NO. 15-7-4
DATA CENTRAL TEST NO. 20489
MAX LOAD -5479 LB.
AREA = 1.0063 x .2654 = .2671 in²
LOAD RATE .05"/MIN
RUN NO. 4
DEFLECTION -.062

SPECIMEN NO. 15-7-5
DATA CENTRAL TEST NO 20489
MAX LOAD -5059 LB
AREA = 1.0066 x .2662 = .2680 in²
LOAD RATE .05"/MIN
RUN NO. 5
DEFLECTION -.062

SPECIMEN NO. 15-7-6
DATA CENTRAL TEST NO 20489
MAX LOAD -5315 LB
AREA = 1.0002 x .2660 = .2660 in²
LOAD RATE .05"/MIN
RUN NO. 6
DEFLECTION -.059

Carl J Looper

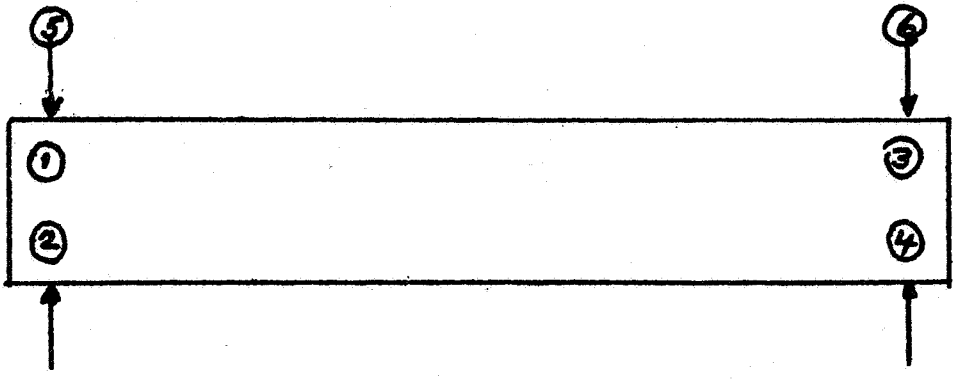
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G. LOOPER

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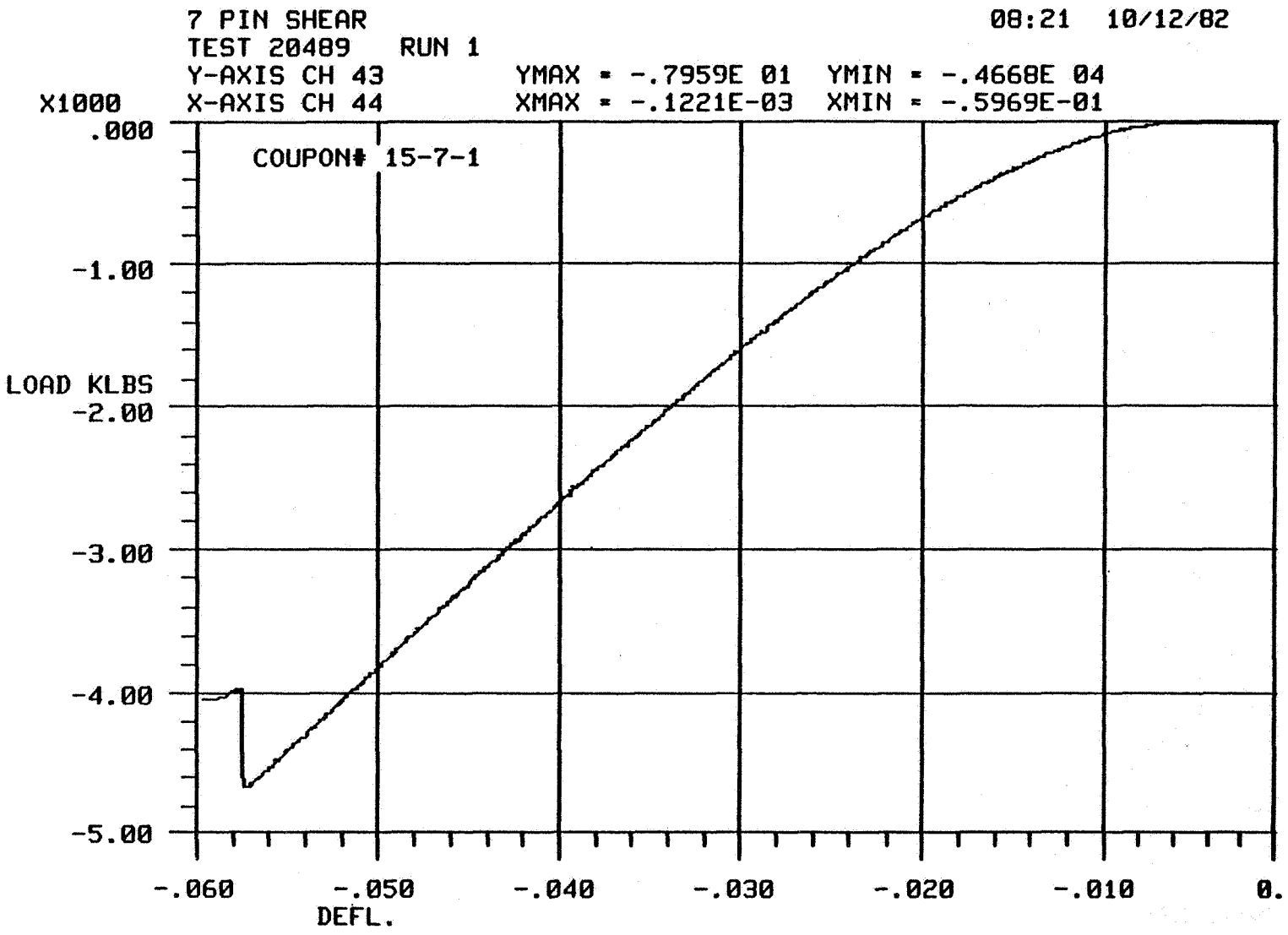
Nº 11544-14

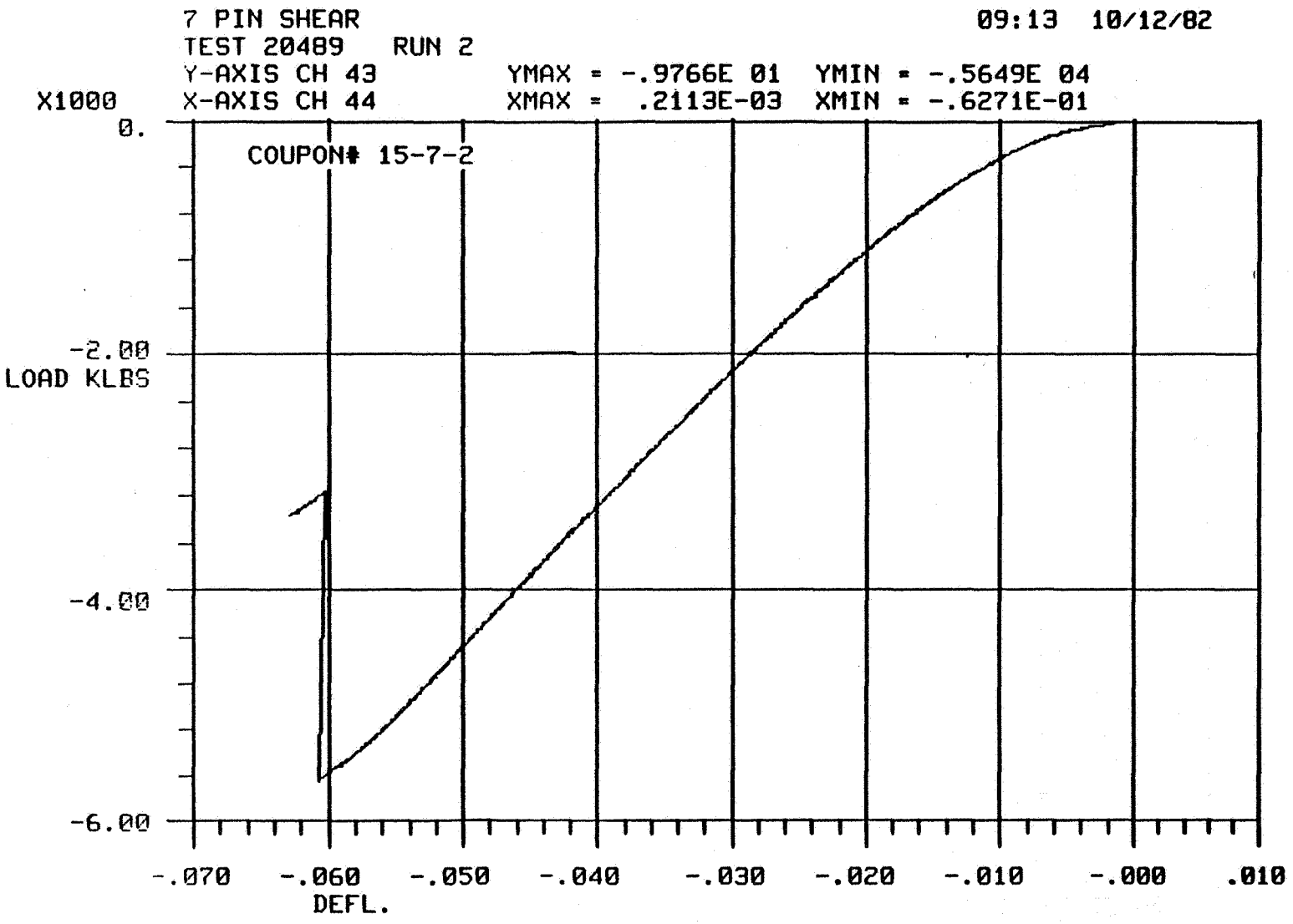
KEY TECHNOLOGY
SHEAR TEST

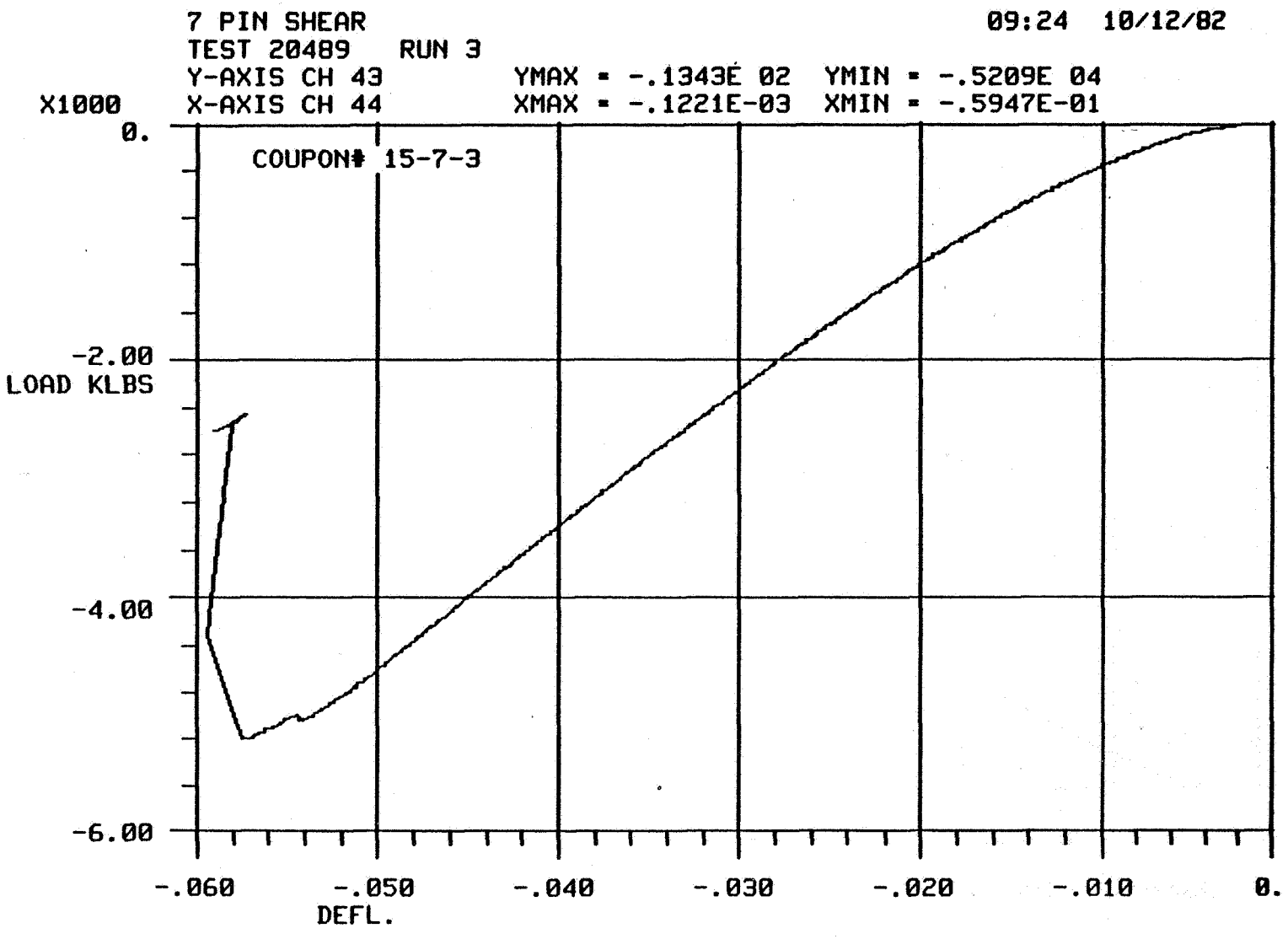


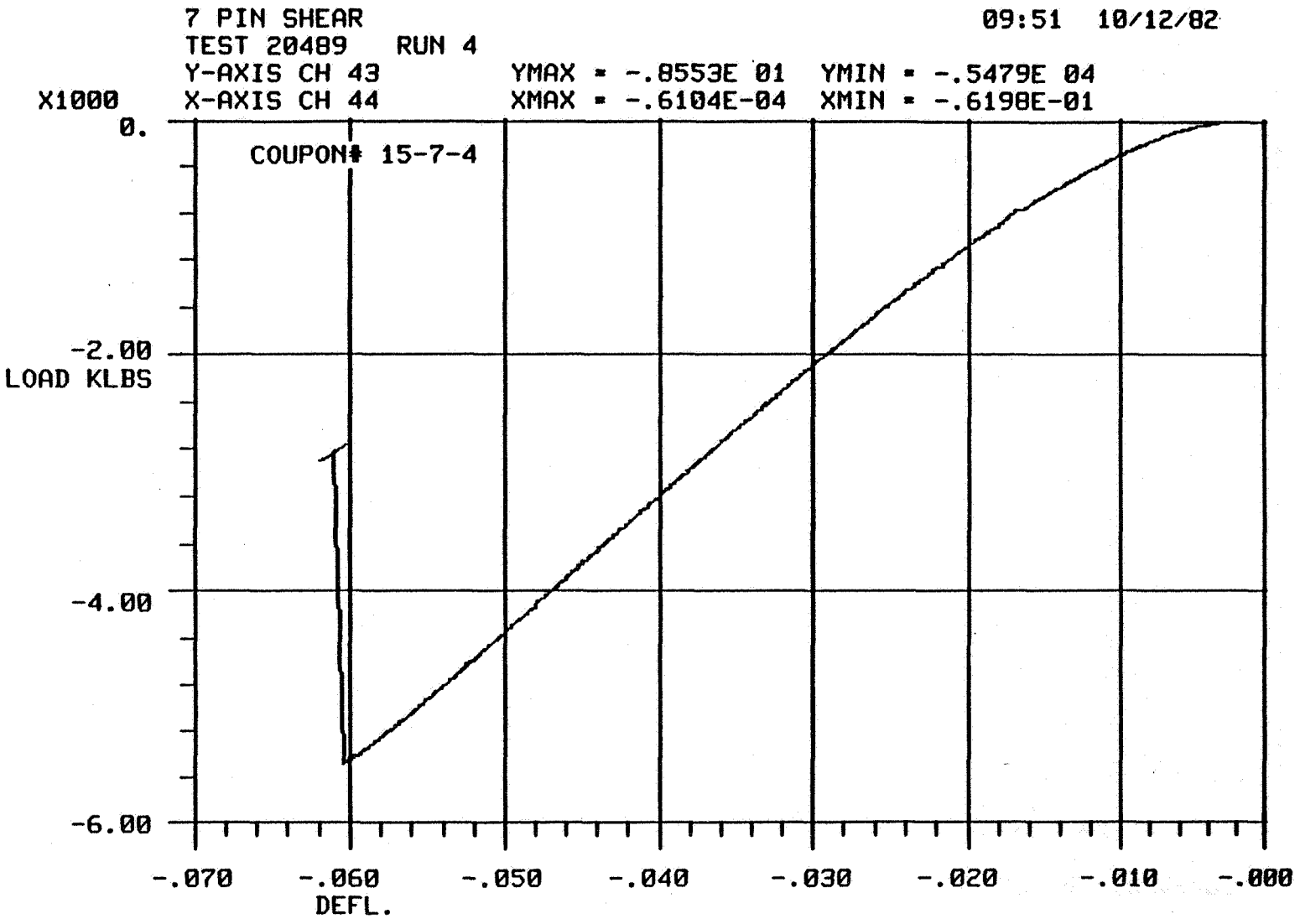
COUPON ID	THICKNESS MEASUREMENTS 1	2	3	4	AVE	WIDTH MEASURE 5	6	AVE
15-7-1	.2666	.2673	.2608	.2602	.2640	.999	.999	.999
15-7-2	.2666	.2672	.2625	.2608	.2650	1.004	1.003	1.004
15-7-3	.2664	.2670	.2617	.2614	.2640	1.005	1.005	1.005
15-7-4	.2670	.2662	.2624	.2621	2640	1.006	1.005	1.006
15-7-5	.2675	.2674	.2598	.2602	.2640	1.005	1.005	1.005
15-7-6	.2668	.2683	.2577	.2581	.2630	.998	1.000	.999

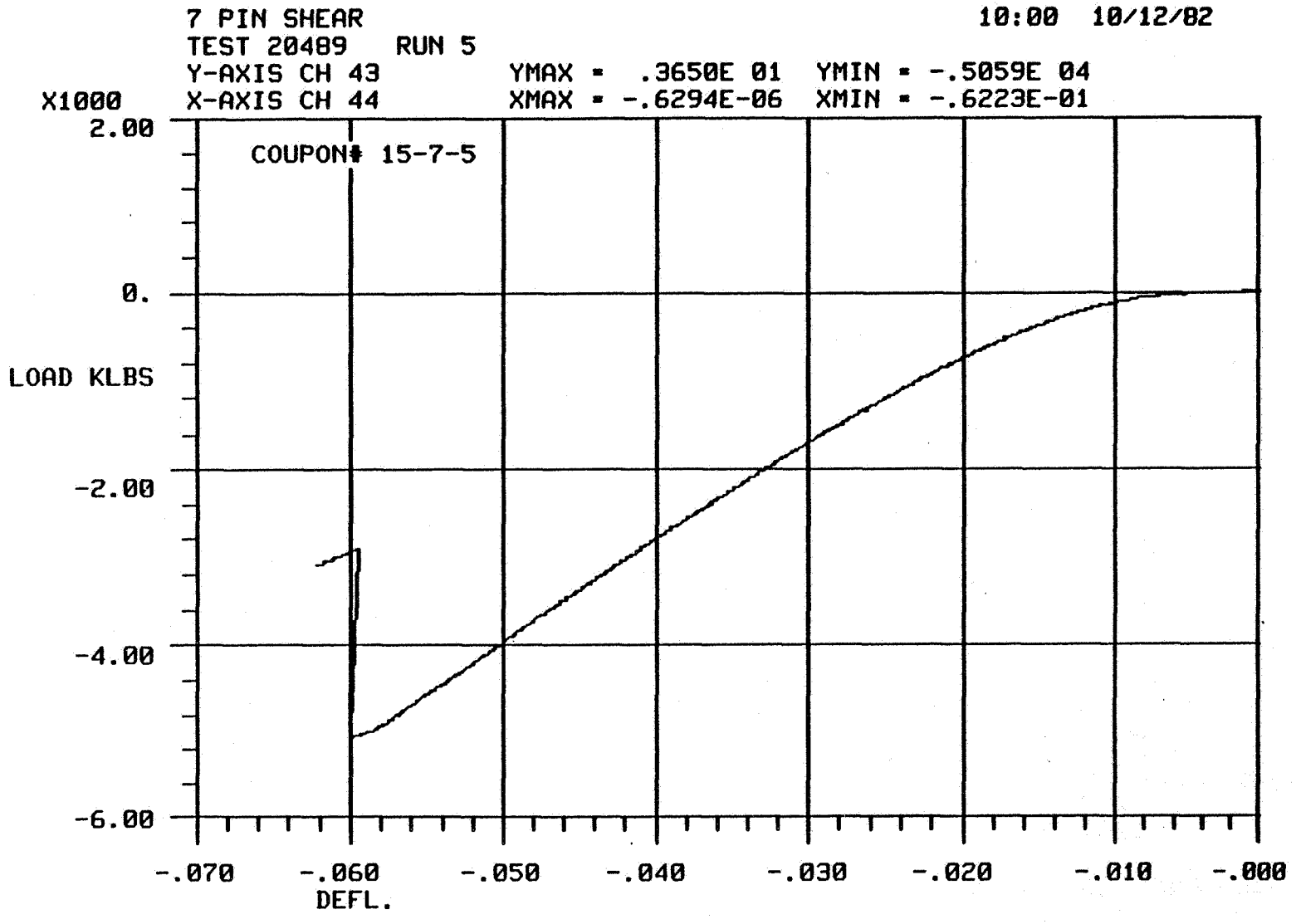
J. Looper

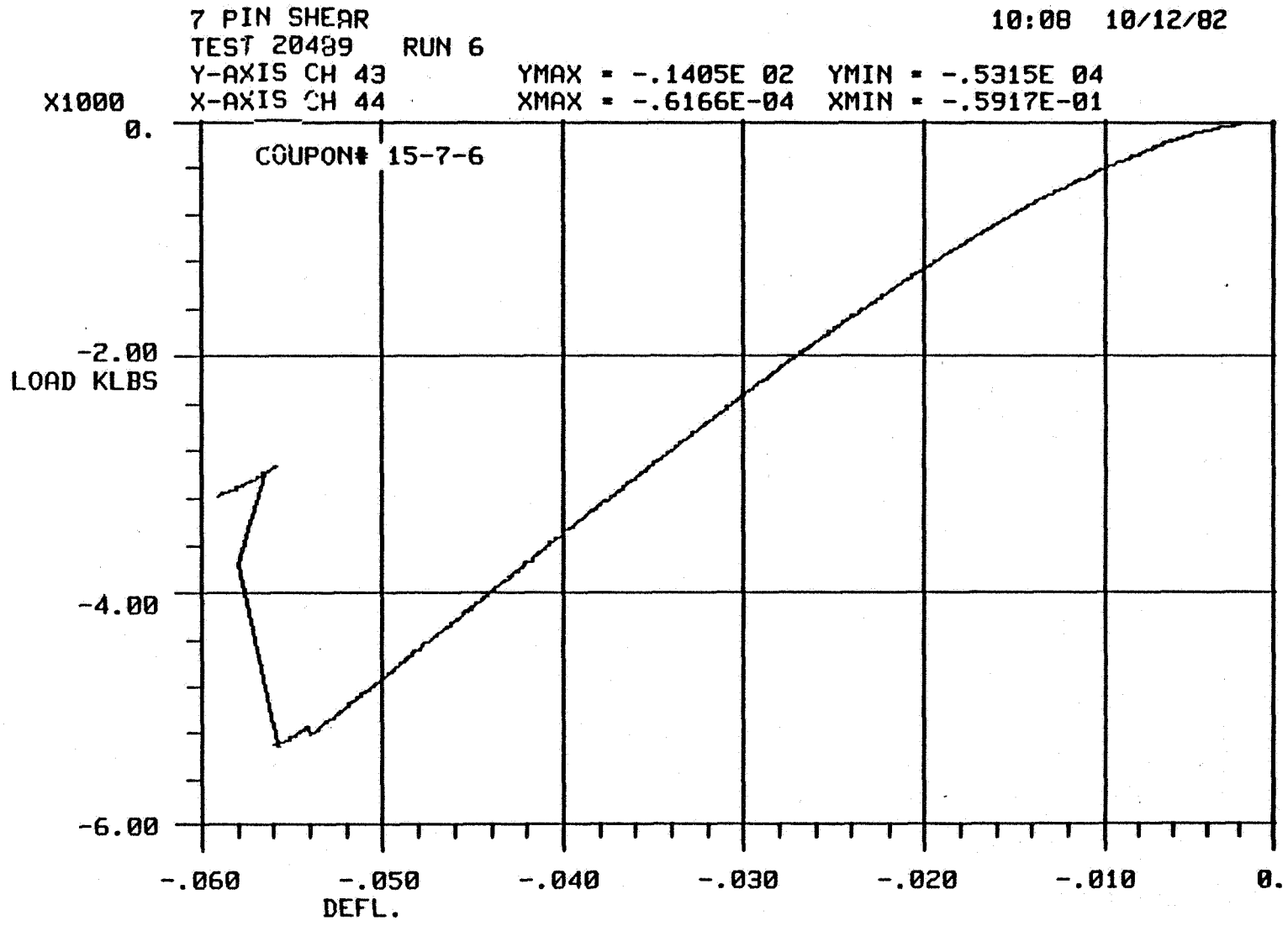

7 PIN SHEAR
08:21 10/12/82
TEST 20489 RUN 1
Y-AXIS CH 43
YMAX = -.7959E 01 YMIN = -.4668E 04
X1000
X-AXIS CH 44
XMAX = -.1221E-03 XMIN = -.5969E-01
.000
COUPON# 15-7-1
-1.00
LOAD KLBS
-2.00
-3.00
-4.00
-5.00
-.060
-.050
-.040
-.030
-.020
-.010
0.
DEFL.


7 PIN SHEAR
09:13 10/12/82
TEST 20489 RUN 2
Y-AXIS CH 43
YMAX = -.9766E 01 YMIN = -.5649E 04
X1000
X-AXIS CH 44
XMAX = .2113E-03 XMIN = -.6271E-01
0.
COUPON# 15-7-2
-2.00
LOAD KLBS
-4.00
-6.00
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
.010
DEFL.


7 PIN SHEAR
09:24 10/12/82
TEST 20489 RUN 3
Y-AXIS CH 43
YMAX = -.1343E 02 YMIN = -.5209E 04
X1000
X-AXIS CH 44
XMAX = -.1221E-03 XMIN = -.5947E-01
0.
COUPON# 15-7-3
-2.00
LOAD KLBS
-4.00
-6.00
-.060
-.050
-.040
-.030
-.020
-.010
0.
DEFL.


7 PIN SHEAR
09:51 10/12/82
TEST 20489 RUN 4
Y-AXIS CH 43
YMAX = -.8553E 01 YMIN = -.5479E 04
X1000
X-AXIS CH 44
XMAX = -.6104E-04 XMIN = -.6198E-01
0.
COUPON# 15-7-4
-2.00
LOAD KLBS
-4.00
-6.00
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
DEFL.


7 PIN SHEAR
10:00 10/12/82
TEST 20489 RUN 5
Y-AXIS CH 43
YMAX = .3650E 01
YMIN = -.5059E 04
X1000
X-AXIS CH 44
XMAX = -.6294E-06
XMIN = -.6223E-01
2.00
COUPON# 15-7-5
0.
LOAD KLBS
-2.00
-4.00
-6.00
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
DEFL.


7 PIN SHEAR
TEST 20489 RUN 6
10:08 10/12/82
Y-AXIS CH 43
X-AXIS CH 44
YMAX = -.1405E 02
YMIN = -.5315E 04
XMAX = -.6166E-04
XMIN = -.5917E-01
X1000
0.
COUPON# 15-7-6
-2.00
LOAD KLBS
-4.00
-6.00
-.060
-.050
-.040
-.030
-.020
-.010
0.
DEFL.

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10/8/82

ENGINEERS NOTEBOOK

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7 PIN SHEAR

SPECIMEN NO. 34-7-1 - LOAD RATE .05"/MIN
DATA CENTRAL TEST NO. 20471 RUN NO. 1 & 2 *
MAX LOAD = -5190 LBS
DEFLECTION ≈ -.089 L = 4.0
AREA = .2441 × .9980 = .2436 IN²
* RUN ONE BOTTOMED OUT - 4000 LB FULL SCALE

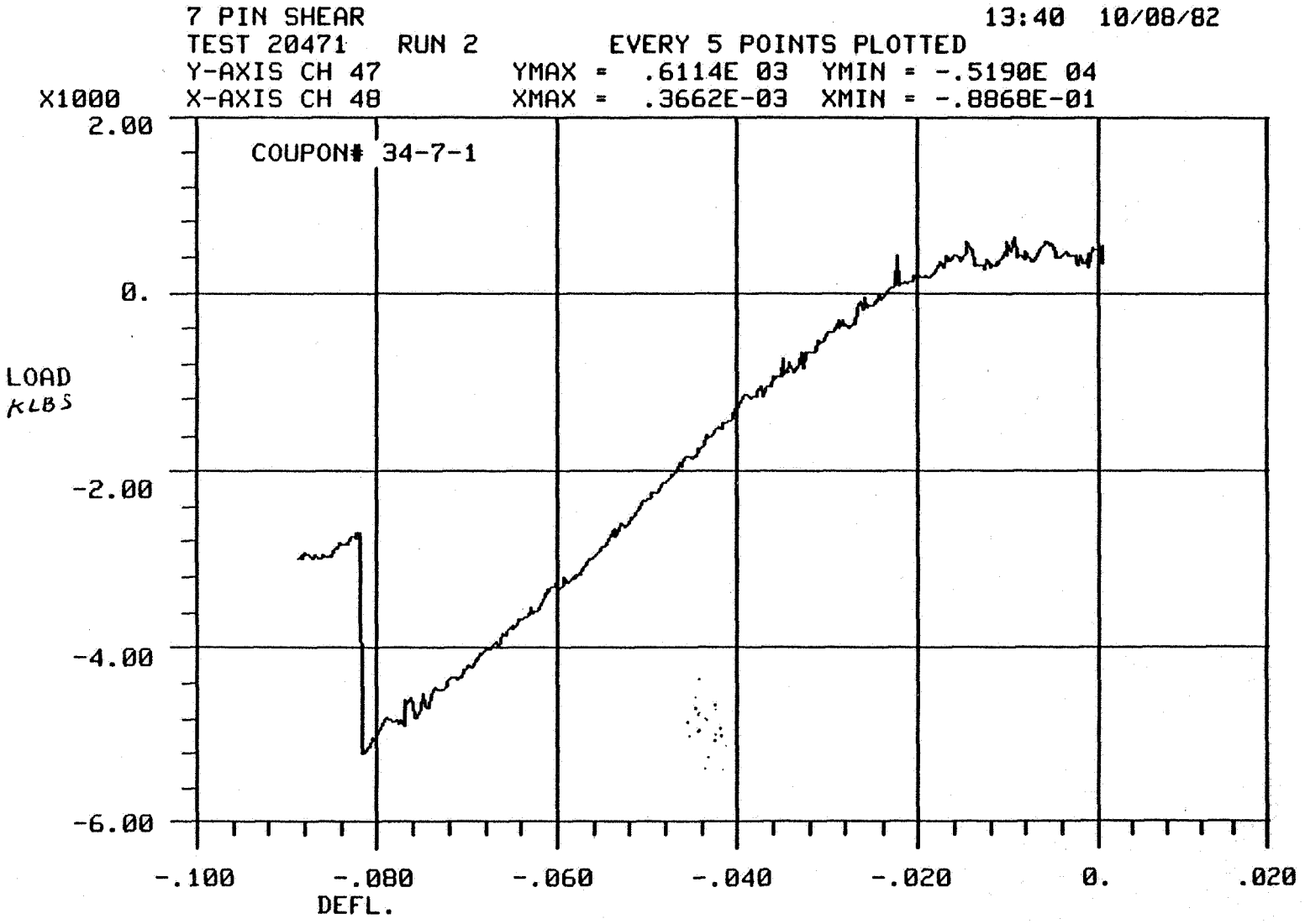
SPECIMEN NO. 34-7-3 - LOAD RATE .05"/MIN
DATA CENTRAL TEST NO. 20471 RUN NO. 3
MAX LOAD = -6099 LBS L = 4.0
DEFLECTION ≈ .078
AREA = .2640 × .9997 = .2639 IN²

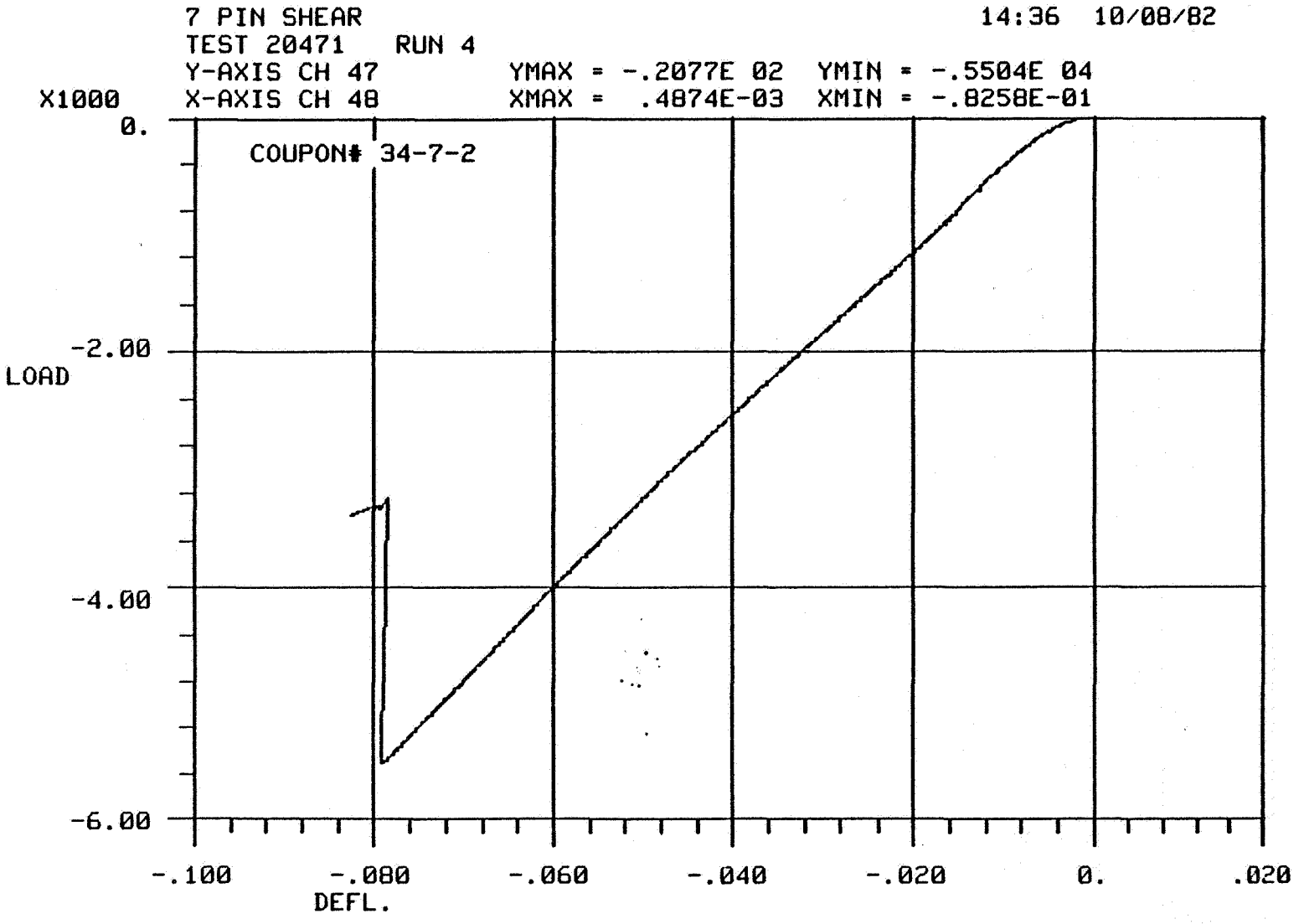
SPECIMEN NO. 34-7-2 - LOAD RATE .05"/MIN
DATA CENTRAL TEST NO. 20471 RUN NO. 4
MAX LOAD - 5504 LB
DEFLECTION ≈ -.084 L = 4.0
AREA = .2551 × 1.0021 = .2556 IN²

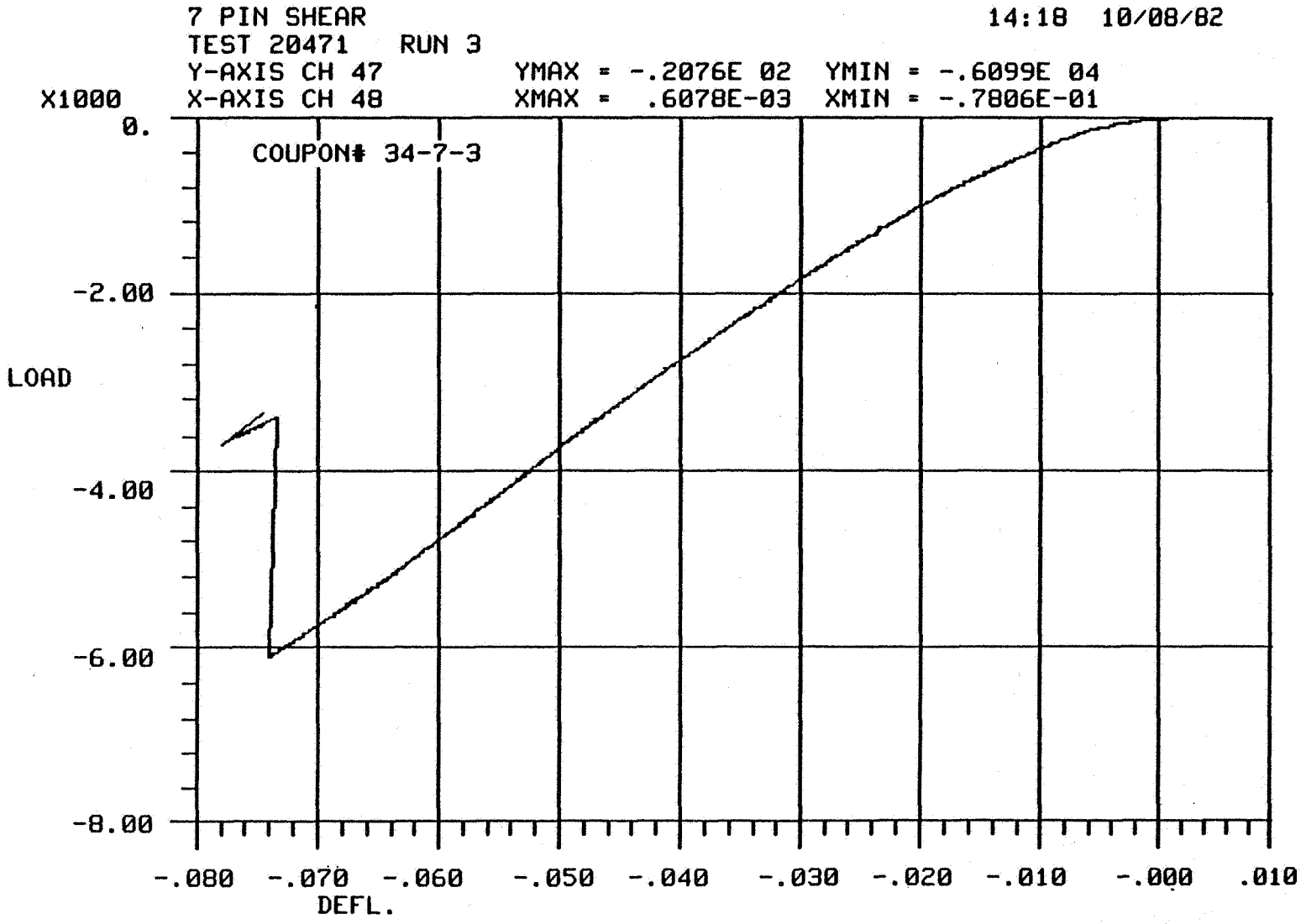
SPECIMEN NO. 34-7-4 - LOAD RATE .05"/MIN
DATA CENTRAL TEST NO 20481 RUN NO 1
MAX LOAD - 5915 LBS L = 4.0
DEFLECTION ≈ -.080
AREA = ~~.2395~~ ≈ .2390 × 1.0027 = .2405 IN²

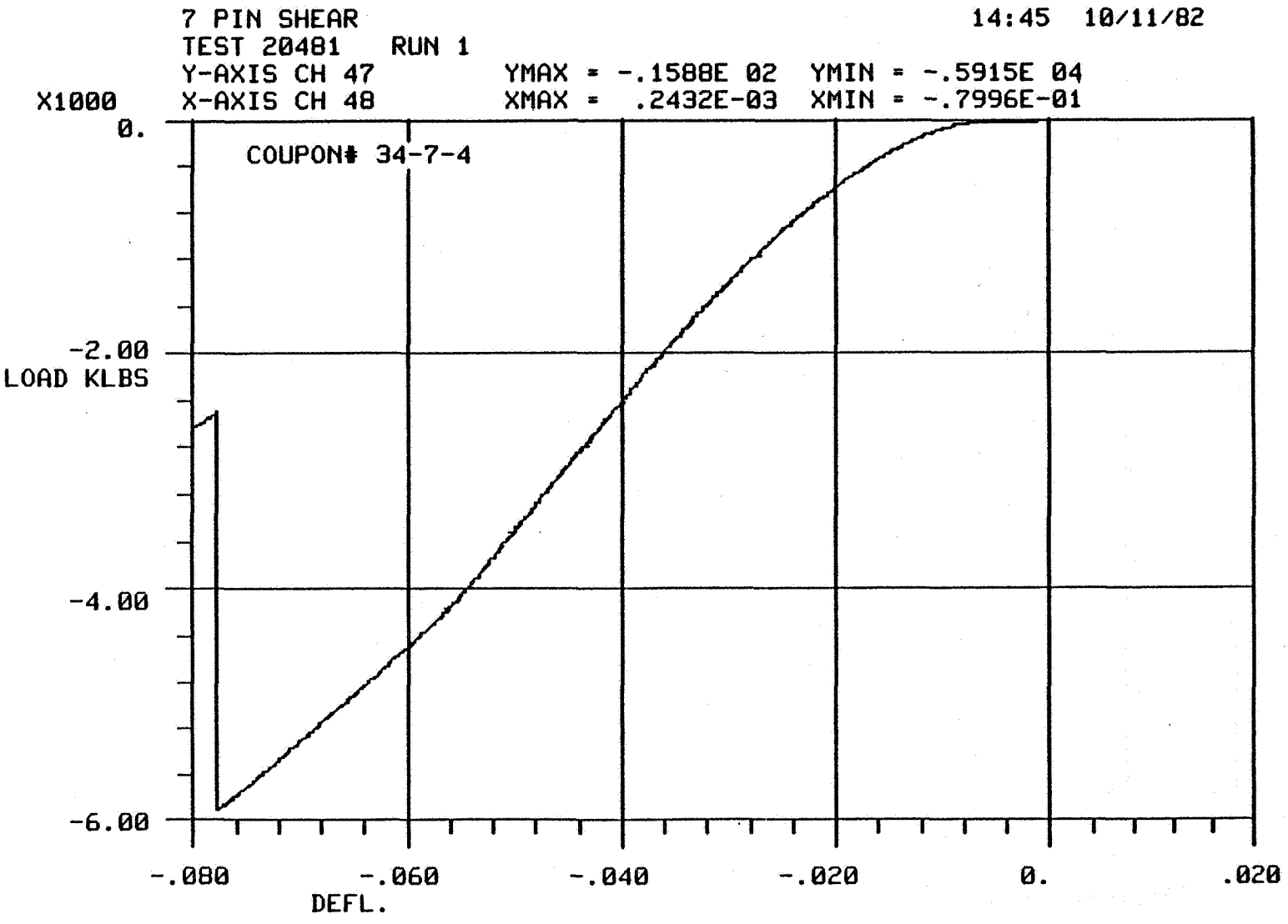
SPECIMEN NO. 34-7~~5~~4 LOAD RATE .05"/MIN
DATA CENTRAL TEST NO 20483 RUN NO. 1
MAX LOAD - 5474 LB
DEFLECTION -.073 L = 4.0
AREA = .9966 × .2494 = 2485 IN²

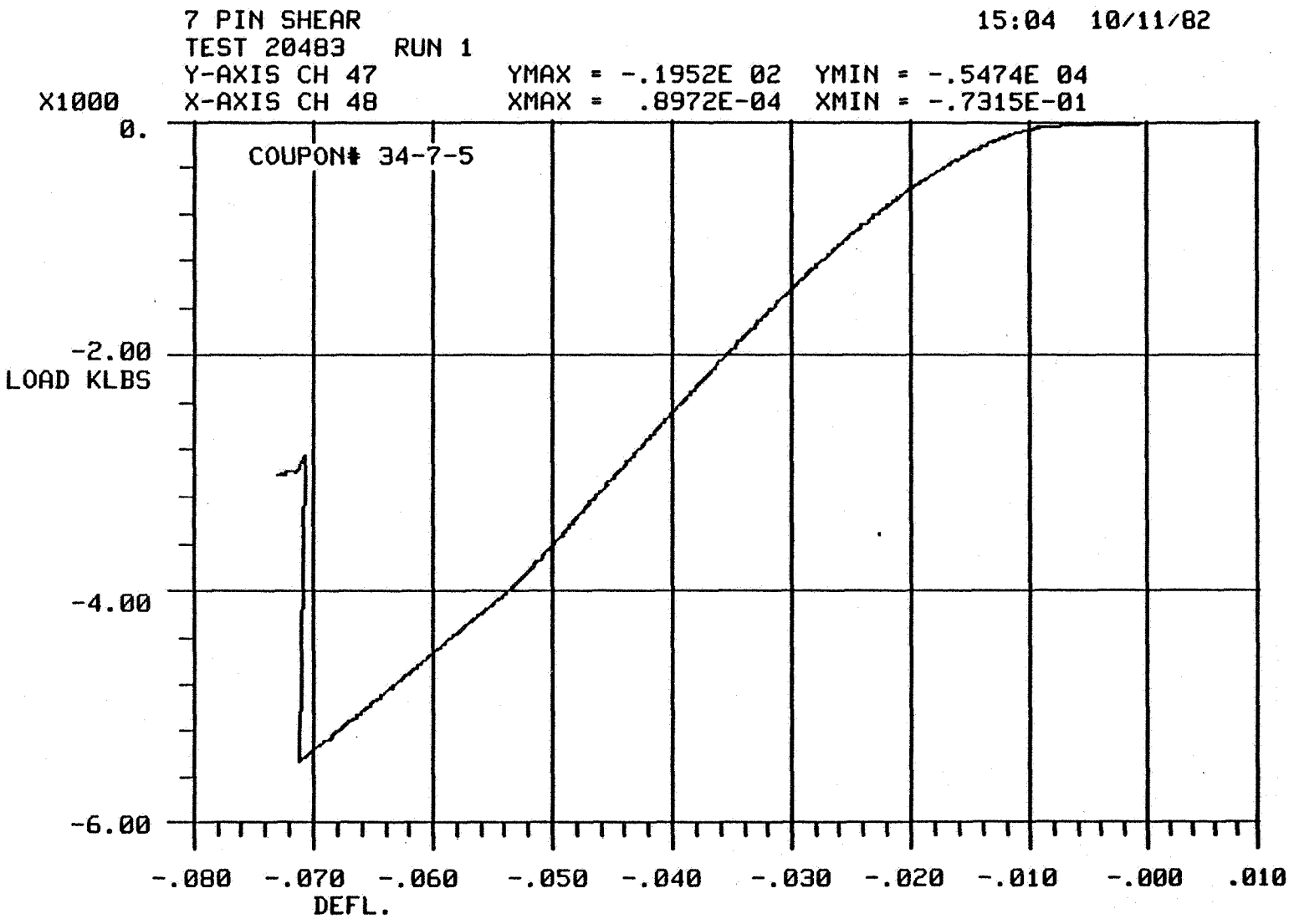
SPECIMEN NO. 34-7-6 LOAD RATE .05"/MIN
DATA CENTRAL TEST NO 20483 RUN NO 2
MAX LOAD - 5942 LB DEFLECTION ~~.0785~~
AREA = .2606 × .9987 = .2603 IN²
LENGTH = 5.0

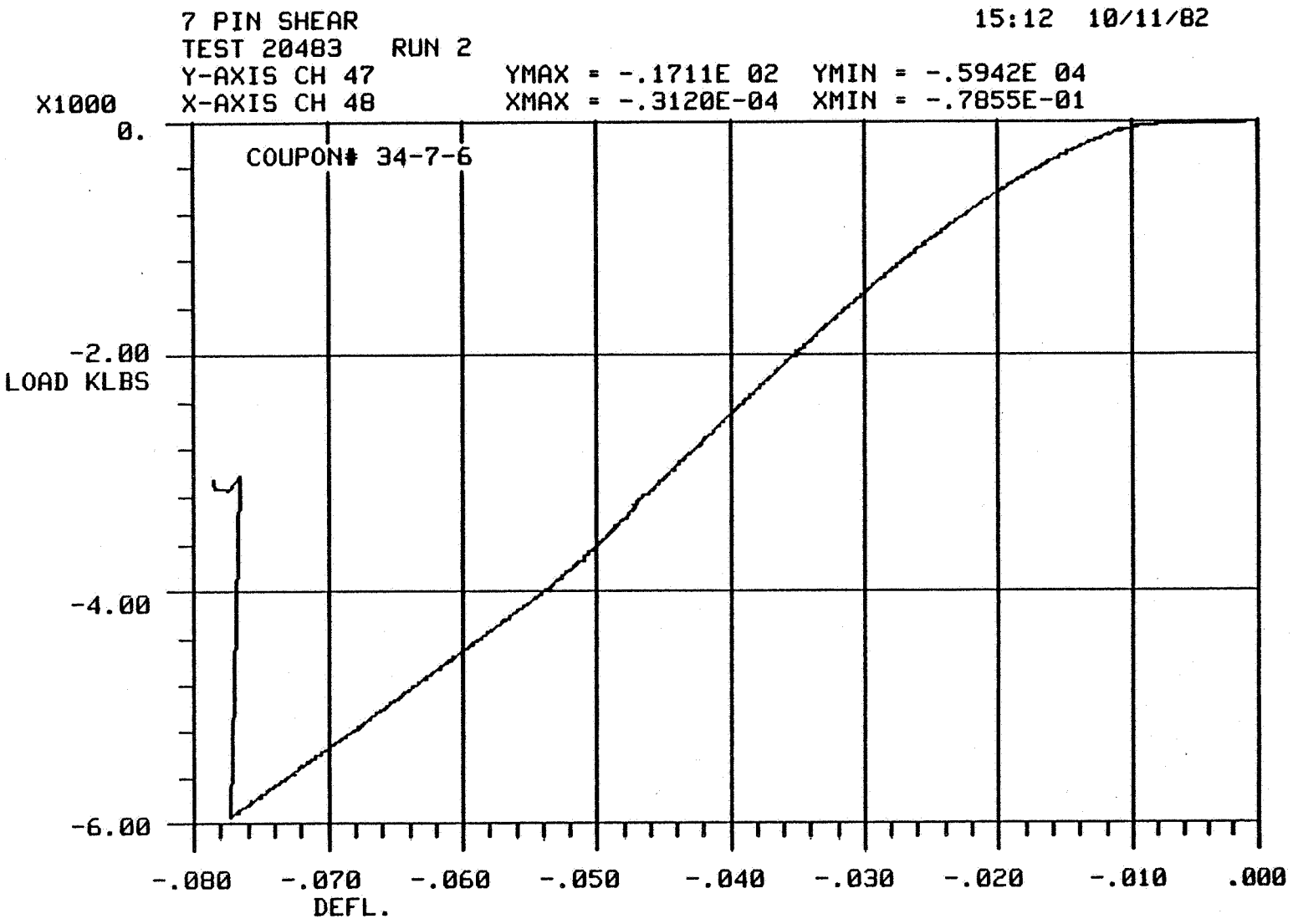

7 PIN SHEAR
13:40 10/08/82
TEST 20471 RUN 2
EVERY 5 POINTS PLOTTED
Y-AXIS CH 47
YMAX = .6114E 03 YMIN = -.5190E 04
X1000
X-AXIS CH 48
XMAX = .3662E-03 XMIN = -.8868E-01
2.00
COUPON# 34-7-1
0.
LOAD
KLBS
-2.00
-4.00
-6.00
-.100
-.080
-.060
-.040
-.020
0.
.020
DEFL.


7 PIN SHEAR
14:36 10/08/82
TEST 20471 RUN 4
Y-AXIS CH 47
YMAX = -.2077E 02
YMIN = -.5504E 04
X1000
X-AXIS CH 48
XMAX = .4874E-03
XMIN = -.8258E-01
0.
COUPON# 34-7-2
-2.00
LOAD
-4.00
-6.00
-.100
-.080
-.060
-.040
-.020
0.
.020
DEFL.


7 PIN SHEAR
14:18 10/08/82
TEST 20471 RUN 3
Y-AXIS CH 47
YMAX = -.2076E 02
YMIN = -.6099E 04
X1000
X-AXIS CH 48
XMAX = .6078E-03
XMIN = -.7806E-01
0.
COUPON# 34-7-3
-2.00
LOAD
-4.00
-6.00
-8.00
-.080
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
.010
DEFL.


7 PIN SHEAR
14:45 10/11/82
TEST 20481 RUN 1
Y-AXIS CH 47
YMAX = -.1588E 02
YMIN = -.5915E 04
X1000
X-AXIS CH 48
XMAX = .2432E-03
XMIN = -.7996E-01
0.
COUPON# 34-7-4
-2.00
LOAD KLBS
-4.00
-6.00
-.080
-.060
-.040
-.020
0.
.020
DEFL.


7 PIN SHEAR
15:04 10/11/82
TEST 20483 RUN 1
Y-AXIS CH 47
YMAX = -.1952E 02
YMIN = -.5474E 04
X1000
X-AXIS CH 48
XMAX = .8972E-04
XMIN = -.7315E-01
0.
COUPON# 34-7-5
-2.00
LOAD KLBS
-4.00
-6.00
-.080
-.070
-.060
-.050
-.040
-.030
-.020
-.010
-.000
.010
DEFL.


7 PIN SHEAR
15:12 10/11/82
TEST 20483 RUN 2
Y-AXIS CH 47
YMAX = -.1711E 02
YMIN = -.5942E 04
X1000
X-AXIS CH 48
XMAX = -.3120E-04
XMIN = -.7855E-01
0.
COUPON# 34-7-6
-2.00
LOAD KLBS
-4.00
-6.00
-.080
-.070
-.060
-.050
-.040
-.030
-.020
-.010
.000
DEFL.

APPENDIX B10

APPENDIX B-10

APPROXIMATE STRESS DISTRIBUTION IN MULTIPLEPOINT SHORT-BEAM-SHEAR

By P. E. Sandorff

INTRODUCTION

A recent development (Reference 1) for assessing interlaminar shear strength of thick graphite/epoxy laminates utilizes geometry similar to the standard ASTM D 2344 short-beam-shear (ASTM SBS) test but with 5-pint or 7-point loading instead of three. The two test conditions are sketched in Figure 1.

From the results of finite element and finite difference analyses (References 2, 3,), the ASTM SBS test for unidirectional laminate is known to develop internal stress distributions and concentrations which depart significantly from the idealized conditions of beam theory that are used in reduction and correlation of the test results. Widely recognized inadequacies of ASTM SBS test, which have limited its application to the perfunctory role of a not-to-be-trusted quality control measure, appear to stem from the complex internal stress conditions. Consequently, a similar investigation of the internal stress distributions in the "multiplepoint short beam shear" test (MP SBS) was considered to be a necessary preliminary to its application or adaption for specific materials test purposes.

APPROACH

The method used for analysis is that described in Reference 3. The material of the laminated test specimen is represented as being homogeneous as well as specially orthotropic. Since the specimens under consideration are 48-ply with at most two adjacent plies of the same orientation, homogeneity in overall behavior is a good first approximation; of course, interactions

between plies superimpose additional local stresses which are not revealed in this study.

On a section through the loading plane of such a model, the stress function must conform to the relation

$$K_z \frac{\partial^4 \phi}{\partial x^4} + 2 \frac{\partial^4 \phi}{\partial x^2 \partial z^2} + K_x \frac{\partial^4 \phi}{\partial z^4} = 0$$

where

$$K_x = (1 - \nu_{xy}^2 E_{yy}/E_{xx})/(E_{xx}/2 G_{xz} - \nu_{xz} - \nu_{zy} \nu_{yx} E_{xx}/E_{zz})$$

$$K_z = (1 - \nu_{zy}^2 E_{yy}/E_{zz})/(E_{zz}/2 G_{xz} - \nu_{zx} - \nu_{xy} \nu_{yz} E_{zz}/E_{xx})$$

By representing the specimen with a grid of closely spaced points and specifying test conditions as loads applied to external points, the stress function at all interior points can be derived to any desired degree of accuracy by applying the above relation repeatedly in finite difference form. This procedure has been implemented in computer programs. Once the stress function matrix is determined, stresses and deflections are calculated by customary methods (Reference 4).

APPROXIMATION OF MATERIAL PROPERTIES

The laminate considered for analysis is of AS4/3502 graphite/epoxy with the layup $(\pm 45/90_2/(\pm 45/0_2)_5)_s$. On the basis of Reference 5 together with the assumption of transverse isotropy and requirements of reciprocity the following elastic properties were assumed for the ply material:

$$E_{11} = 20.1 \text{ Msi}$$
$$E_{22}, E_{33} = 1.60 \text{ Msi}$$
$$G_{12}, G_{13} = 0.88 \text{ Msi}$$

$$G_{23} = 0.53 \text{ Msi}$$
$$\nu_{12}, \nu_{13} = 0.31$$
$$\nu_{23}, \nu_{32} = 0.50$$
$$\nu_{21}, \nu_{31} = 0.025$$

The equivalent elastic constants of the laminate were derived by summation of the transformed ply stiffnenss, inversion of the matrix, and identification through the corresponding compliances (Reference 6). These equivalent constants are:

$$E_{xx} = 10.60 \text{ Msi}$$
$$E_{yy} = 5.05 \text{ Msi}$$
$$E_{zz} = 1.97 \text{ Msi}$$
$$G_{yz} = 0.65 \text{ Msi}$$
$$G_{xz} = 0.76 \text{ Msi}$$
$$G_{xy} = 2.95 \text{ Msi}$$

$$\nu_{xy} = 0.47$$
$$\nu_{yx} = 0.22$$
$$\nu_{yz} = 0.39$$
$$\nu_{zy} = 0.15$$
$$\nu_{xz} = 0.25$$
$$\nu_{zx} = 0.046$$

RESULTS

The analysis was applied to both the ASTM SBS and the MP SBS test configurations under comparable conditions. The specimen geometries were:

ASTM SBS - 1.550 in. long, supports at 1.000 centers, with load P in center.

MP SBS - Continuous, with loads P alternately in opposite directions every 0.500 in.

These are sketched in Figure 1. The MP SBS case does not exactly represent either 5-point or 7-point test condition, but rather the extreme condition of many-point load; differences from the ASTM SBS are therefore emphasized. Solutions were developed for a value of P = 5000 lb on 1.00-inch wide specimens. The grid spacing usid for the MP SBS configuration was 0.0125 x 0.0125 inch; for the ASTM SBS configuration the spacing in the beam length direction was doubled, for programming reasons. In either case, the solution was carried to an estimated 99 percent completion or better.

Copies of the computer print-outs are furnished in the accompanying Tables 1 through 10. These show, at each of the grid points, values of

Stress Function
Axial Stress (σ_{xx})
Transverse Stress (σ_{zz})
Shear Stress (τ_{xz})
Beam Deflections

Plots of the shear stress (τ_{xz}) distribution for the two cases are provided in Figures 2 and 3.

DISCUSSION

The results are in general similar to those documented previously in Reference 3.

In summary:

- Stresses depart significantly from beam theory in regions adjacent to the stations of load application. Shear stress distribution is grossly distorted and peak values may be as much as double that computed by the usual formula 0.75 p/h. Bending compression stress also peaks in the fibers directly under the application of transverse load.
- Midway between load application stations the stress

distributions and the values of stress conform closely to beam theory.

A comparison of the two test configurations will be aided by reference to the shear and moment diagrams, Figure 4, and shear stress and axial stress diagrams, Figures 5 and 6. It is seen that overstress conditions are more severe in the continuous beam under multiple-point loads. While the shear load in this configuration is the same as that in the ASTM SBS specimen, the maximum moment is only half as great. However, the configuration or recurrent equal and opposite loads forces symmetry and complete restraint against warping at each loading station. Consequently, only a distance L/4 is available over which the internal stresses and deformations can adapt to the freely warped state which must apply at the intermediate stations of moment inflexion. As a result, effects of warping restraint are more severe for the MP SBS, resulting in much higher peak shear stresses, and in a peak bending stress almost as large as that in the ASTM SBS, despite the reduction in maximum moment.

Recognized limitations of this analysis include the following:

- Laminates are represented as homogeneous with respect to material properties. Equilibrium of stresses at ply interfaces requires, in general, that some plies carry higher stress than the solution would indicate, while others carry lower stress.
- The analysis assumes linear elasticity. Graphite/epoxy properties, particularly shear stiffnesses, do not conform, although the departure is not considered so great that it would negate qualitative conclulsions regarding conditions at incipient failure.

CONCLUSIONS

1. The multiple-point short beam shear (MP SBS) test configuration provides higher peak shear stress and lower peak bending stress than the ASTM short beam shear (ASTM SBS) test, for specimens of equal size

and material properties. This may be an advantage in tests of laminates which tend to fail in fiber rupture or combined mode.

2. From the results of this analysis, the MP SBS configuration would not be expected to improve accuracy in the determination of interlaminar shear strength, when failure is clearly in this mode. Analysis for internal stress distributions indicates that stress peaks and distortions are even more severe than in the case of the ASTM SBS. This condition could be expected to lead to a greater sensitivity to local material variations and to increased test scatter. In any case, the determination of actual shear stress at the point of failure does not appear to be possible with either of these test configurations.

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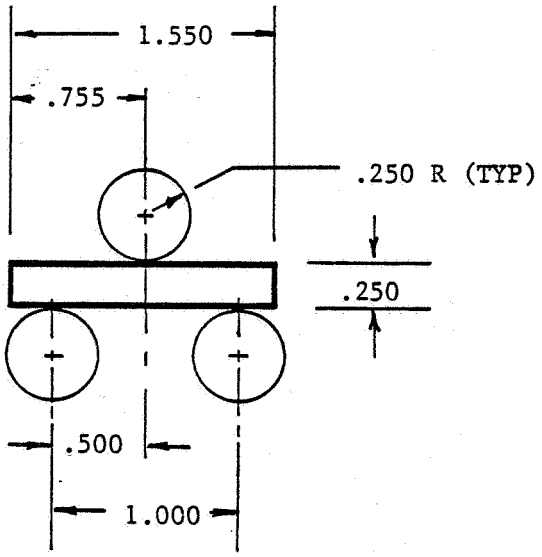
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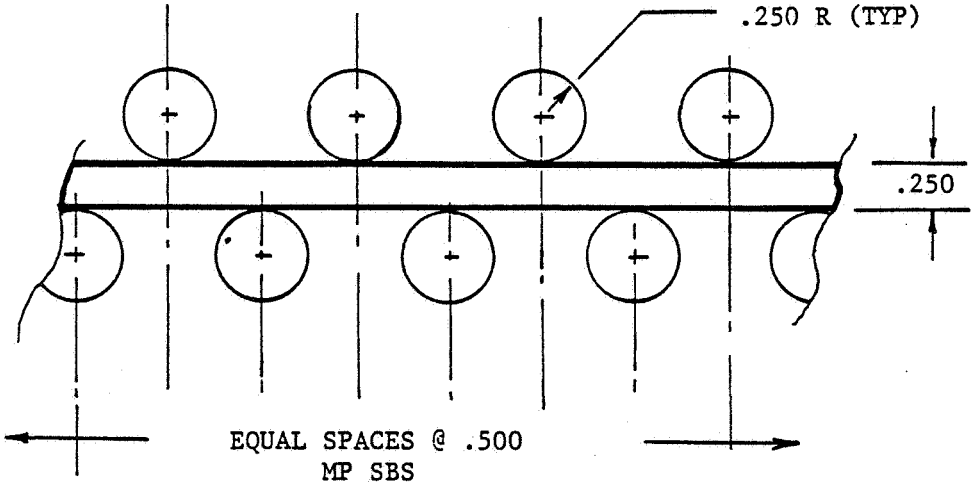
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ASTM SBS



MP SBS

Figure 1: Test Configurations as Modeled in Computer Analysis.

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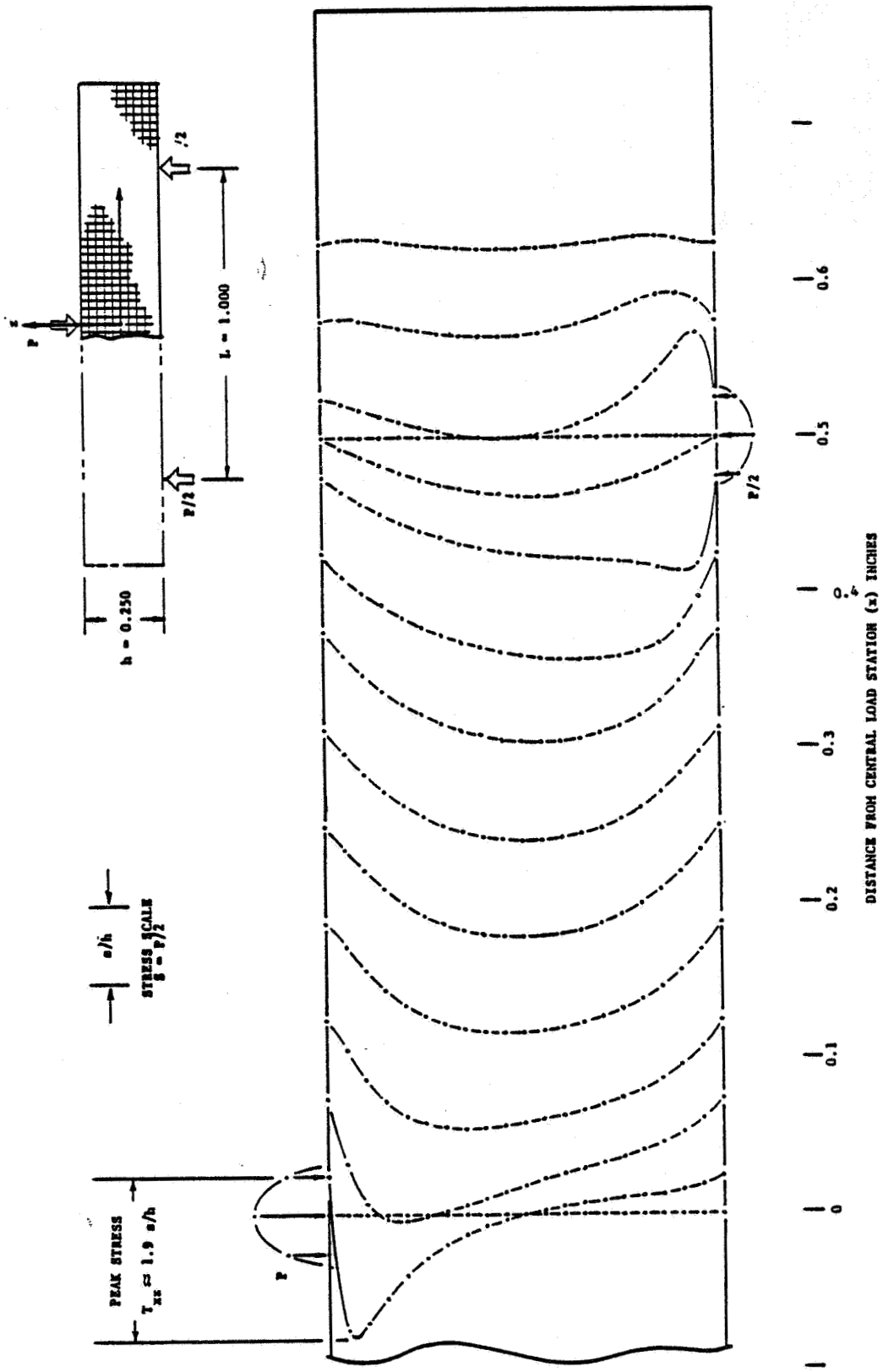


Figure 2. Shear Stress Distribution in ASTM SBS.

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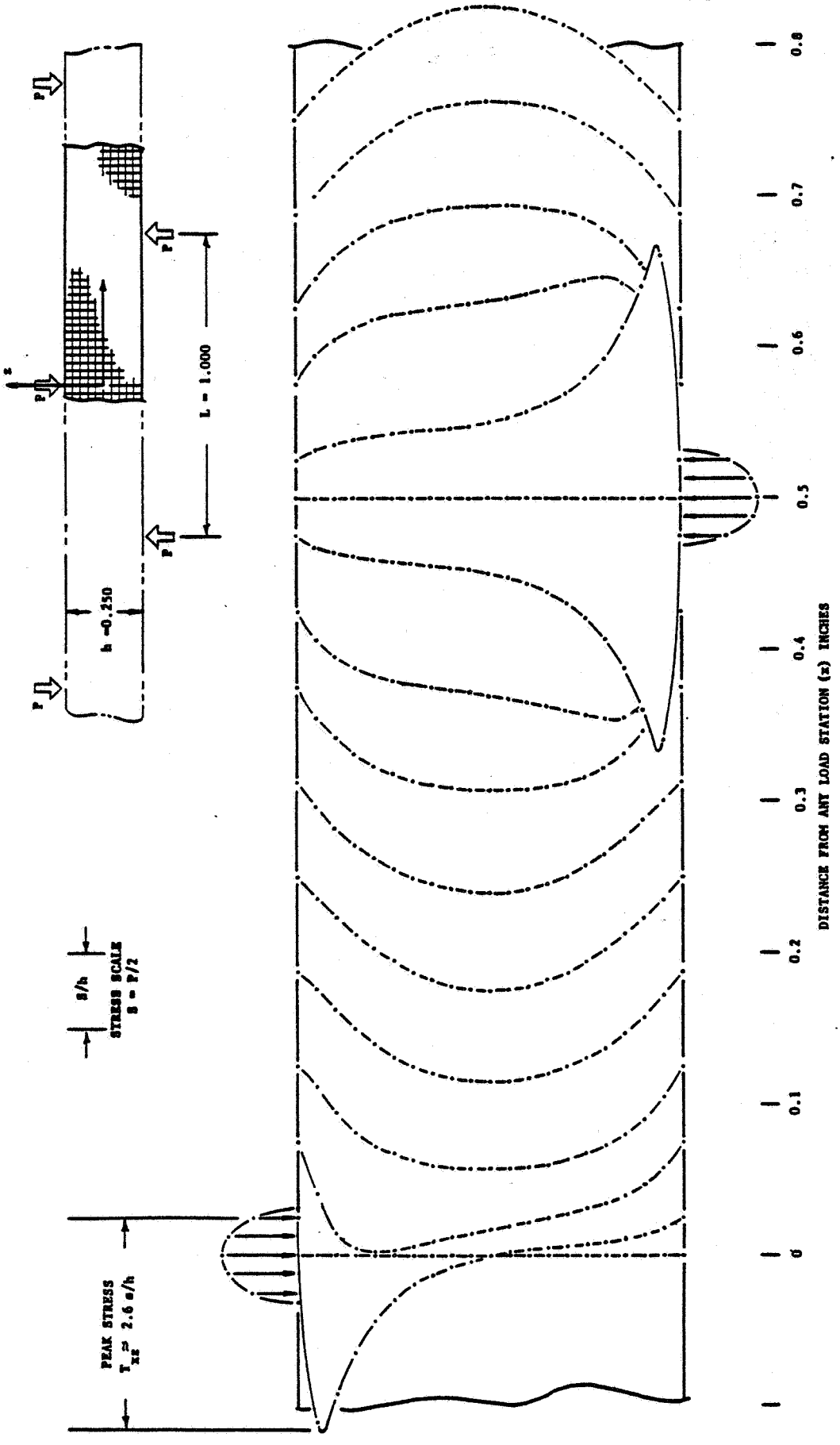


Figure 3. Shear Stress Distribution in MP SBS.

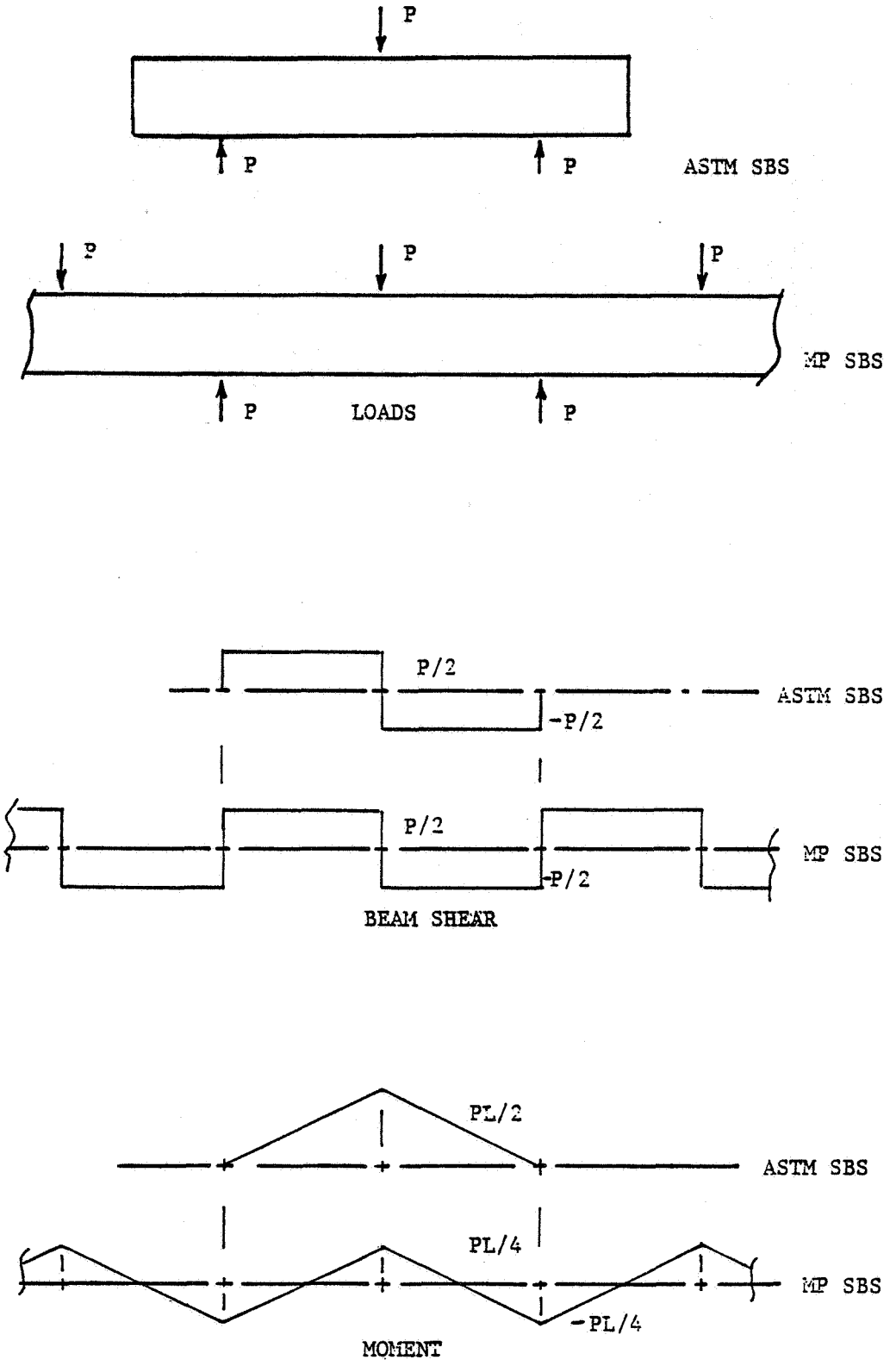


Figure 4: Load, Shear and Moment Diagrams Compared.

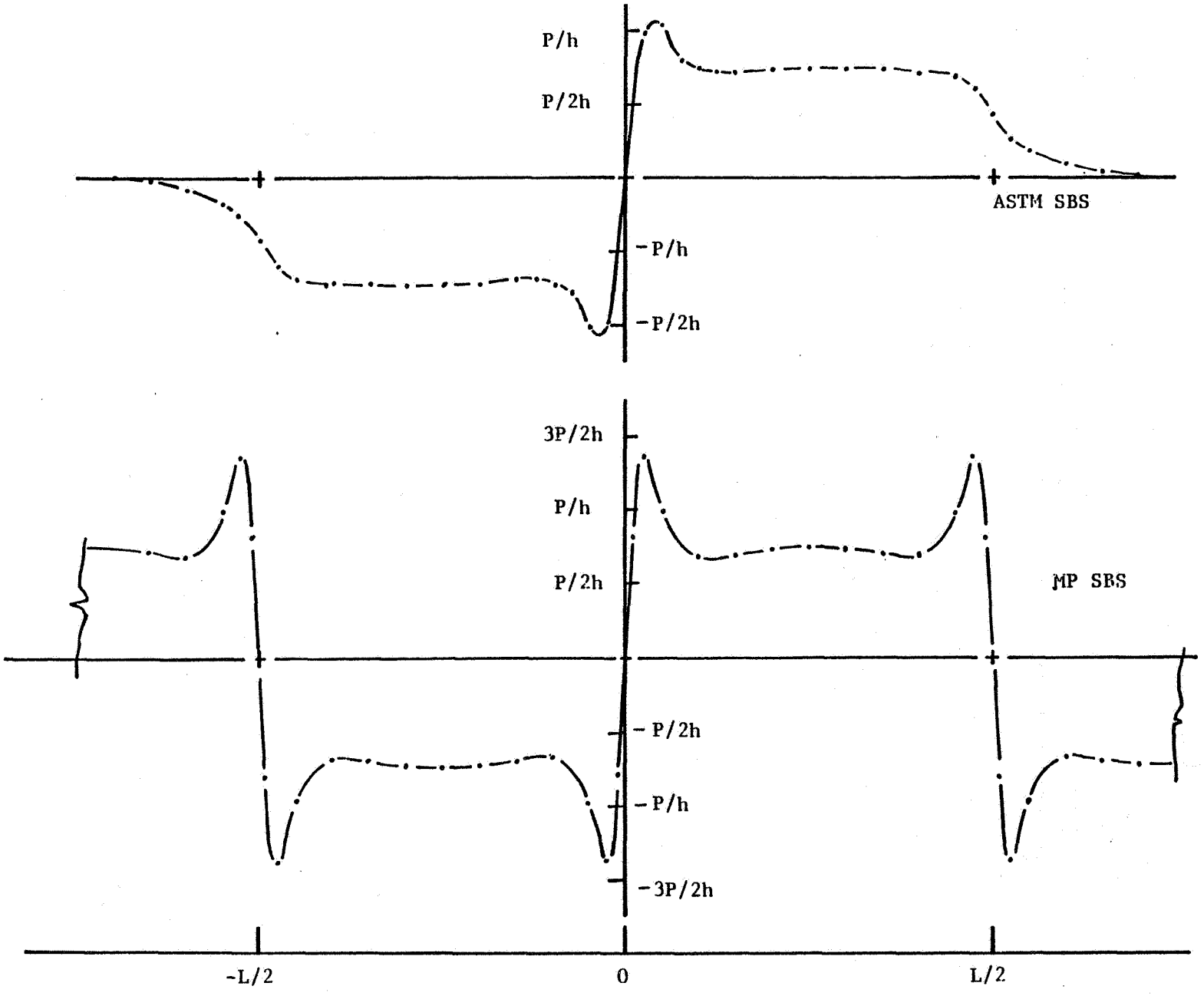


Figure 5: Peak Shear Stress Distribution Along Span.

TABLE 1. INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

12/14/82 1400 hrs

INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 021213

PLANE STRAIN: Kx= .136751 , Kz= .95 Sh= 2500 P= 5000

L= 1 h= .25 W= 1.000 Lc= .25 Lp= .03125 aa= .0125 bb= .0125 Sh= 2500 P= 5000

Stress function matrix is:

i	j=-1	j=0	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11
0	5.892	0.000	5.579	19.295	38.978	63.151	90.777	121.100	153.546	187.653	223.038	259.369	296.361
1	5.842	0.000	5.545	19.186	38.769	62.824	90.318	120.497	152.785	186.721	221.919	258.044	294.803
2	5.724	0.000	5.443	18.863	38.150	61.857	88.960	118.710	150.533	183.965	218.614	254.134	290.218
3	5.542	0.000	5.277	18.338	37.144	60.284	86.750	115.805	146.875	179.495	213.265	247.826	282.850
4	5.304	0.000	5.054	17.632	35.788	58.159	83.766	111.881	141.940	173.475	206.081	239.387	273.045
5	5.018	0.000	4.784	16.770	34.127	55.551	80.099	107.062	135.884	166.102	197.307	229.122	261.184
6	4.695	0.000	4.476	15.779	32.209	52.536	75.854	101.482	128.877	157.584	187.197	217.337	247.634
7	4.343	0.000	4.139	14.688	30.088	49.189	71.137	95.277	121.088	148.127	175.995	204.319	232.730
8	3.972	0.000	3.784	13.524	27.813	45.588	66.048	88.577	112.676	137.920	163.924	190.323	216.758
9	3.591	0.000	3.419	12.313	25.430	41.800	60.683	81.502	103.788	127.137	151.182	175.573	199.965
10	3.206	0.000	3.050	11.076	22.979	37.888	55.124	74.158	94.551	115.927	137.940	160.258	182.556
11	2.824	0.000	2.683	9.831	20.495	33.902	49.443	66.634	85.075	104.418	124.342	144.538	164.703
12	2.450	0.000	2.325	8.597	18.012	29.895	43.708	59.017	75.462	92.726	110.516	128.551	146.551
13	2.085	0.000	1.976	7.379	15.542	25.889	37.952	51.352	65.770	80.923	96.548	112.392	128.204
14	1.732	0.000	1.638	6.184	13.101	21.909	32.212	43.686	56.056	69.075	82.512	96.145	109.751
15	1.392	0.000	1.313	5.022	10.705	17.978	26.519	36.059	46.369	57.238	68.471	79.875	91.260
16	1.068	0.000	1.006	3.899	8.369	14.121	20.906	28.512	36.755	45.465	54.480	63.641	72.791
17	0.766	0.000	0.719	2.827	6.109	10.360	15.402	21.080	27.256	33.800	40.587	47.492	54.391
18	0.490	0.000	0.459	1.816	3.945	6.724	10.044	13.807	17.920	22.293	26.840	31.472	36.102
19	0.242	0.000	0.227	0.875	1.898	3.250	4.883	6.750	8.805	11.000	13.289	15.625	17.961
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	-0.242	0.000	-0.227	-0.875	-1.898	-3.250	-4.883	-6.750	-8.805	-11.000	13.289	-15.625	-17.961
22	-0.484	0.000	-0.453	-1.750	-3.797	-6.500	-9.766	-13.500	-17.609	-22.000	-26.578	-31.250	-35.922
23	-0.727	0.000	-0.680	-2.625	-5.695	-9.750	-14.648	-20.250	-26.414	33.000	-39.867	-46.875	-53.883

i	j=9	j=10	j=11	j=12	j=13	j=14	j=15	j=16	j=17	j=18	j=19	j=20	j=21
0	223.038	259.369	296.361	333.758	371.323	408.811	445.927	482.249	517.081	549.200	576.204	592.200	575.892
1	221.919	258.044	294.803	331.933	369.184	406.293	442.941	478.669	512.737	543.866	569.636	584.451	569.339
2	218.614	254.134	290.218	326.579	362.934	398.972	434.310	468.398	500.370	528.794	551.140	562.499	550.867
3	213.265	247.826	282.850	318.022	353.016	387.465	420.906	452.687	481.804	506.651	524.571	534.249	524.306
4	206.081	239.387	273.045	306.714	340.029	372.577	403.837	433.096	459.308	480.888	495.468	500.000	495.210
5	197.307	229.122	261.184	293.131	324.576	355.073	384.075	410.853	434.384	453.212	465.349	468.750	465.115
6	187.197	217.337	247.634	277.717	307.186	335.583	362.354	386.786	407.917	424.449	434.756	437.500	434.537
7	175.995	204.319	232.730	260.855	288.294	314.591	339.200	361.442	380.431	395.028	403.920	406.250	403.717
8	163.924	190.323	216.758	242.864	268.246	292.463	314.990	335.186	352.248	365.188	372.953	375.000	372.766
9	151.182	175.573	199.965	224.007	247.320	269.482	289.997	308.271	323.581	335.076	341.913	343.750	341.741
10	137.940	160.258	182.556	204.502	225.739	245.868	264.430	280.881	294.575	304.783	310.831	312.500	310.675
11	124.342	144.538	164.703	184.528	203.682	221.797	238.452	253.154	265.335	274.374	279.728	281.250	279.587
12	110.516	128.551	146.551	164.233	181.295	197.405	212.182	225.191	235.935	243.889	248.614	250.000	248.487
13	96.548	112.392	128.204	143.729	158.695	172.807	185.730	197.083	206.441	213.366	217.500	218.750	217.391
14	82.512	96.145	109.751	123.105	135.970	148.088	159.171	168.894	176.901	182.830	186.392	187.500	186.298
15	68.471	79.875	91.260	102.432	113.189	123.313	132.562	140.670	147.345	152.296	155.292	156.250	155.214
16	54.480	63.641	72.791	81.768	90.407	98.531	105.947	112.444	117.795	121.775	124.203	125.000	124.140
17	40.587	47.492	54.391	61.158	67.667	73.782	79.359	84.243	88.270	91.275	93.127	93.750	93.080
18	26.840	31.472	36.102	40.642	45.005	49.098	52.826	56.089	58.783	60.806	62.066	62.500	62.054
19	13.289	15.625	17.961	20.250	22.445	24.500	26.367	28.000	29.352	30.375	31.023	31.250	31.008
20	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
21	-13.289	-15.625	-17.961	20.250	-22.445	-24.500	-26.367	-28.000	-29.352	30.375	-31.023	-31.250	31.008
22	-26.578	-31.250	-35.922	-40.500	-44.891	-49.000	-52.734	-56.000	-58.703	-60.750	-62.047	-62.500	-62.016
23	-39.867	-46.875	53.883	-60.750	-67.336	-73.500	-79.102	-84.000	-88.055	-91.125	93.070	-93.750	-93.023

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TABLE 2. INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 W= 1.000 Lc= .25 Lp= .03125 aa= .0125 bb= .0125 Sh= 2500 P= 5000

Axial stresses (ksi) are:

i	j=0	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11	j=12
0	73.42	52.07	38.19	28.74	22.10	17.26	13.58	10.64	8.17	6.06	4.23	2.60	1.07
1	72.87	51.82	38.03	28.63	22.01	17.18	13.50	10.55	8.07	5.93	4.06	2.38	0.77
2	71.46	51.06	37.55	28.28	21.74	16.94	13.27	10.30	7.78	5.58	3.60	1.78	-0.04
3	69.24	49.82	36.77	27.73	21.30	16.56	12.90	9.92	7.36	5.07	2.96	0.95	-1.14
4	66.29	48.15	35.70	26.97	20.71	16.06	12.44	9.45	6.85	4.48	2.25	0.06	-2.26
5	62.74	46.09	34.38	26.04	19.99	15.46	11.90	8.93	6.32	3.90	1.58	-0.73	-3.22
6	58.69	43.69	32.82	24.93	19.15	14.78	11.31	8.40	5.80	3.37	1.01	-1.37	-3.93
7	54.28	41.02	31.05	23.69	18.21	14.04	10.69	7.86	5.31	2.91	0.56	-1.83	-4.39
8	49.64	38.12	29.11	22.31	17.19	13.24	10.05	7.33	4.86	2.53	0.23	-2.11	-4.63
9	44.86	35.04	27.03	20.82	16.08	12.39	9.39	6.81	4.45	2.21	0.01	-2.24	-4.66
10	40.04	31.85	24.82	19.23	14.90	11.50	8.71	6.29	4.07	1.96	-0.13	-2.26	-4.54
11	35.25	28.57	22.50	17.55	13.66	10.56	8.00	5.77	3.71	1.75	-0.20	-2.18	-4.29
12	30.56	25.26	20.12	15.80	12.35	9.58	7.27	5.24	3.37	1.56	-0.22	-2.04	-3.96
13	25.99	21.93	17.67	13.98	10.98	8.55	6.51	4.71	3.02	1.40	-0.21	-1.84	-3.57
14	21.56	18.61	15.17	12.10	9.57	7.49	5.73	4.16	2.68	1.25	-0.17	-1.61	-3.13
15	17.31	15.33	12.64	10.17	8.11	6.40	4.92	3.59	2.32	1.10	-0.12	-1.36	-2.66
16	13.27	12.08	10.09	8.21	6.61	5.26	4.08	2.99	1.95	0.94	-0.08	-1.10	-2.16
17	9.51	8.89	7.52	6.20	5.06	4.07	3.19	2.36	1.55	0.76	-0.04	-0.84	-1.66
18	6.07	5.75	4.94	4.16	3.46	2.83	2.24	1.67	1.11	0.55	-0.01	-0.57	-1.14
19	3.00	2.70	2.40	2.10	1.80	1.50	1.20	0.90	0.60	0.30	-0.00	-0.30	-0.60
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	-3.00	-2.70	-2.40	-2.10	-1.80	-1.50	-1.20	-0.90	-0.60	-0.30	0.00	0.30	0.60

Axial stresses (ksi) (continued):

i	j=13	j=14	j=15	j=16	j=17	j=18	j=19	j=20
0	-0.49	-2.37	-5.09	-9.53	-17.37	-32.73	-70.46	-206.75
1	-0.91	-2.95	-5.89	-10.62	-18.81	-34.30	-70.11	-191.53
2	-2.02	-4.48	-8.00	-13.53	-22.71	-38.85	-70.42	-147.10
3	-3.49	-6.45	-10.63	-17.04	-27.33	-44.33	-71.95	-87.18
4	-4.91	-8.24	-12.80	-19.51	-29.64	-44.80	-64.30	-59.61
5	-6.06	-9.57	-14.23	-20.77	-30.10	-42.82	-55.91	-45.03
6	-6.86	-10.41	-14.97	-21.12	-29.44	-39.84	-48.40	-36.52
7	-7.31	-10.80	-15.15	-20.82	-28.10	-36.51	-42.00	-31.12
8	-7.46	-10.82	-14.91	-20.06	-26.38	-33.12	-36.60	-27.40
9	-7.37	-10.54	-14.34	-18.97	-24.41	-29.82	-32.00	-24.62
10	-7.08	-10.03	-13.51	-17.64	-22.30	-26.63	-28.02	-22.36
11	-6.65	-9.35	-12.49	-16.14	-20.10	-23.59	-24.52	-20.38
12	-6.10	-8.53	-11.32	-14.50	-17.85	-20.67	-21.37	-18.53
13	-5.47	-7.61	-10.04	-12.77	-15.58	-17.86	-18.46	-16.69
14	-4.78	-6.63	-8.70	-10.99	-13.30	-15.15	-15.70	-14.79
15	-4.05	-5.59	-7.31	-9.17	-11.03	-12.51	-13.04	-12.77
16	-3.30	-4.53	-5.88	-7.34	-8.78	-9.93	-10.44	-10.61
17	-2.52	-3.44	-4.44	-5.49	-6.53	-7.39	-7.86	-8.28
18	-1.73	-2.34	-2.97	-3.64	-4.30	-4.88	-5.28	-5.76
19	-0.90	-1.20	-1.50	-1.80	-2.10	-2.40	-2.70	-3.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.90	1.20	1.50	1.80	2.10	2.40	2.70	3.00

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TABLE 3. INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 021213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 W= 1.000 Lc= .25 Lp= .03125 aa= .0125 bb= .0125 Sh= 2500 P= 5000

Transverse stresses (ksi) are:

i	j=0	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11	j=12
0	0.00	-0.44	-1.40	-2.67	-4.18	-5.87	-7.72	-9.74	-11.93	-14.32	-16.96	-19.94	-23.36
1	0.00	-0.43	-1.37	-2.62	-4.10	-5.76	-7.58	-9.55	-11.68	-13.99	-16.54	-19.37	-22.59
2	0.00	-0.41	-1.29	-2.47	-3.88	-5.45	-7.16	-9.00	-10.97	-13.08	-15.35	-17.81	-20.50
3	0.00	-0.36	-1.16	-2.24	-3.53	-4.96	-6.52	-8.17	-9.92	-11.74	-13.64	-15.60	-17.61
4	0.00	-0.31	-1.00	-1.96	-3.09	-4.36	-5.73	-7.17	-8.66	-10.17	-11.69	-13.16	-14.55
5	0.00	-0.24	-0.82	-1.64	-2.61	-3.70	-4.87	-6.09	-7.33	-8.55	-9.72	-10.80	-11.72
6	0.00	-0.18	-0.64	-1.30	-2.11	-3.03	-4.00	-5.01	-6.02	-6.99	-7.89	-8.67	-9.27
7	0.00	-0.12	-0.46	-0.99	-1.63	-2.37	-3.17	-3.98	-4.79	-5.56	-6.26	-6.83	-7.23
8	0.00	-0.07	-0.30	-0.69	-1.19	-1.77	-2.40	-3.05	-3.69	-4.30	-4.83	-5.26	-5.54
9	0.00	-0.02	-0.16	-0.43	-0.80	-1.24	-1.72	-2.23	-2.73	-3.20	-3.61	-3.94	-4.15
10	0.00	0.02	-0.05	-0.21	-0.47	-0.78	-1.15	-1.53	-1.91	-2.28	-2.59	-2.85	-3.00
11	0.00	0.05	0.06	-0.00	-0.14	-0.35	-0.60	-0.88	-1.17	-1.46	-1.71	-1.92	-2.05
12	0.00	0.06	0.11	0.09	0.01	-0.13	-0.30	-0.50	-0.71	-0.91	-1.09	-1.24	-1.34
13	0.00	0.07	0.15	0.19	0.17	0.10	-0.01	-0.15	-0.29	-0.44	-0.57	-0.69	-0.77
14	0.00	0.09	0.20	0.29	0.32	0.31	0.26	0.18	0.08	-0.03	-0.14	-0.24	-0.31
15	0.00	0.11	0.26	0.38	0.47	0.50	0.50	0.47	0.40	0.32	0.23	0.14	0.05
16	0.00	0.13	0.32	0.49	0.62	0.70	0.74	0.74	0.70	0.63	0.54	0.45	0.35
17	0.00	0.17	0.39	0.61	0.80	0.93	1.02	1.04	1.00	0.93	0.83	0.71	0.60
18	0.00	0.18	0.45	0.76	1.04	1.26	1.38	1.42	1.37	1.26	1.11	0.95	0.79
19	0.00	0.04	0.42	0.95	1.43	1.78	1.96	1.99	1.88	1.67	1.42	1.15	0.91
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	0.00	-0.00	0.00	-0.00	-0.00	-0.00	-0.00	0.00	0.00	0.00	0.00	-0.00	-0.00

Transverse stresses (ksi) (continued):

i	j=13	j=14	j=15	j=16	j=17	j=18	j=19	j=20
0	-27.37	-32.22	-38.22	-45.82	-55.60	-68.27	-84.07	-99.19
1	-26.32	-30.74	-36.13	-42.83	-51.35	-62.32	-76.29	-90.89
2	-23.47	-26.79	-30.55	-34.81	-39.68	-45.25	-51.77	-59.51
3	-19.65	-21.64	-23.46	-24.83	-25.15	-23.17	-16.17	0.00
4	-15.78	-16.74	-17.23	-16.98	-15.54	-12.25	-6.50	-0.00
5	-12.39	-12.71	-12.54	-11.67	-9.88	-6.96	-3.04	0.00
6	-9.62	-9.62	-9.17	-8.17	-6.52	-4.21	-1.55	0.00
7	-7.40	-7.26	-6.77	-5.84	-4.45	-2.68	-0.84	0.00
8	-5.62	-5.46	-5.00	-4.22	-3.10	-1.75	-0.47	0.00
9	-4.20	-4.05	-3.67	-3.04	-2.17	-1.15	-0.26	0.00
10	-3.04	-2.93	-2.64	-2.15	-1.49	-0.75	-0.14	0.00
11	-2.11	-2.05	-1.86	-1.52	-1.03	-0.49	-0.07	0.00
12	-1.37	-1.32	-1.17	-0.92	-0.59	-0.24	-0.00	-0.00
13	-0.80	-0.77	-0.68	-0.52	-0.30	-0.09	0.03	0.00
14	-0.36	-0.36	-0.32	-0.23	-0.10	0.01	0.06	0.00
15	-0.01	-0.04	-0.04	-0.01	0.04	0.08	0.07	-0.00
16	0.27	0.21	0.17	0.16	0.15	0.14	0.08	0.00
17	0.49	0.41	0.35	0.30	0.25	0.19	0.10	0.00
18	0.66	0.56	0.48	0.42	0.35	0.25	0.12	0.00
19	0.73	0.63	0.58	0.57	0.51	0.36	0.12	0.00
20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
21	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00	-0.00

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TABLE 4. INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 W= 1.000 Lc= .25 Lp= .03125 aa= .0125 bb= .0125 Sh= 2500 P= 5000

Shear stresses (ksi) are:

i	j=0	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11	j=12
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	-0.05	0.69	1.11	1.38	1.58	1.75	1.91	2.08	2.26	2.47	2.75	3.11	3.59
2	-0.05	1.36	2.17	2.71	3.11	3.44	3.75	4.05	4.39	4.79	5.28	5.91	6.74
3	-0.05	1.97	3.16	3.95	4.53	5.01	5.44	5.86	6.30	6.81	7.42	8.19	9.17
4	-0.05	2.51	4.04	5.06	5.81	6.42	6.94	7.44	7.95	8.50	9.13	9.90	10.84
5	-0.05	2.97	4.80	6.03	6.93	7.64	8.24	8.79	9.31	9.86	10.44	11.11	11.89
6	-0.05	3.33	5.43	6.85	7.88	8.68	9.33	9.90	10.42	10.92	11.43	11.96	12.52
7	-0.05	3.61	5.93	7.51	8.66	9.53	10.23	10.81	11.32	11.76	12.16	12.54	12.90
8	-0.05	3.80	6.30	8.02	9.27	10.22	10.95	11.54	12.02	12.41	12.72	12.96	13.13
9	-0.05	3.92	6.56	8.40	9.74	10.75	11.52	12.12	12.58	12.92	13.15	13.27	13.29
10	-0.05	3.97	6.72	8.67	10.09	11.15	11.96	12.56	13.00	13.31	13.47	13.51	13.40
11	-0.05	3.97	6.79	8.82	10.32	11.44	12.28	12.90	13.33	13.61	13.73	13.70	13.50
12	-0.05	3.92	6.79	8.90	10.46	11.63	12.50	13.14	13.58	13.84	13.93	13.85	13.58
13	-0.05	3.86	6.76	8.92	10.54	11.75	12.66	13.31	13.76	14.01	14.07	13.96	13.64
14	-0.05	3.77	6.68	8.89	10.55	11.81	12.75	13.43	13.88	14.13	14.19	14.05	13.70
15	-0.05	3.66	6.56	8.80	10.52	11.82	12.79	13.50	13.97	14.23	14.28	14.13	13.76
16	-0.05	3.51	6.40	8.68	10.43	11.78	12.79	13.53	14.03	14.31	14.38	14.22	13.84
17	-0.05	3.33	6.20	8.50	10.30	11.69	12.76	13.55	14.09	14.40	14.48	14.33	13.94
18	-0.05	3.12	5.95	8.25	10.09	11.55	12.69	13.55	14.15	14.51	14.61	14.47	14.07
19	-0.05	2.91	5.58	7.85	9.76	11.33	12.60	13.58	14.27	14.69	14.82	14.67	14.25
20	-0.05	2.80	5.35	7.60	9.55	11.20	12.55	13.60	14.35	14.80	14.95	14.80	14.35
21	-0.05	2.80	5.35	7.60	9.55	11.20	12.55	13.60	14.35	14.80	14.95	14.80	14.35

Shear stresses (ksi) (continued):

i	j=13	j=14	j=15	j=16	j=17	j=18	j=19	j=20
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	4.26	5.16	6.42	8.15	10.49	13.35	14.87	-0.05
2	7.87	9.39	11.45	14.24	17.97	22.61	25.58	-0.05
3	10.45	12.11	14.25	16.94	20.17	23.39	23.35	-0.05
4	12.00	13.43	15.11	16.94	18.57	18.88	14.50	-0.05
5	12.80	13.82	14.91	15.85	16.21	14.91	9.70	-0.05
6	13.13	13.75	14.28	14.53	14.04	11.96	6.91	-0.05
7	13.23	13.48	13.57	13.29	12.26	9.81	5.18	-0.05
8	13.22	13.17	12.90	12.23	10.85	8.25	4.08	-0.05
9	13.17	12.88	12.34	11.38	9.76	7.12	3.35	-0.05
10	13.13	12.65	11.89	10.72	8.94	6.30	2.88	-0.05
11	13.11	12.49	11.56	10.23	8.33	5.72	2.57	-0.05
12	13.11	12.38	11.33	9.87	7.90	5.33	2.39	-0.05
13	13.10	12.30	11.17	9.63	7.62	5.10	2.30	-0.05
14	13.12	12.26	11.07	9.49	7.45	4.98	2.29	-0.05
15	13.15	12.26	11.03	9.41	7.37	4.93	2.31	-0.05
16	13.21	12.29	11.03	9.40	7.35	4.94	2.37	-0.05
17	13.29	12.35	11.08	9.42	7.38	5.00	2.45	-0.05
18	13.40	12.43	11.14	9.48	7.45	5.10	2.56	-0.05
19	13.53	12.51	11.19	9.53	7.55	5.25	2.71	-0.05
20	13.60	12.55	11.20	9.55	7.60	5.35	2.80	-0.05
21	13.60	12.55	11.20	9.55	7.60	5.35	2.80	-0.05

TABLE 5. INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

INFINITELY LONG BEAM - MULTIPLE POINT LOADING - MP SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .95 Sh= 2500 P= 5000
L= 1 h= .25 W= 1.000 Lc= .25 Lp= .03125 aa= .0125 bb= .0125 Sh= 2500 P= 5000

Deformations are:

Sta	(du/dz)fx	(du/dz)fz	gamma	(wb)fx-in.	(wb)fz-in.	ws-in.	wt-in.
0	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1	-0.00014665	0.00005295	0.00361900	0.00000092	-0.00000033	0.00002251	0.00002310
2	-0.00029951	0.00010215	0.00694307	0.00000369	-0.00000131	0.00008925	0.00009163
3	-0.00046543	0.00014334	0.00976659	0.00000846	-0.00000285	0.00019400	0.00019962
4	-0.00064359	0.00017674	0.01201920	0.00001538	-0.00000486	0.00033103	0.00034155
5	-0.00083380	0.00020178	0.01374270	0.00002460	-0.00000723	0.00049228	0.00050965
6	-0.00102979	0.00022110	0.01503630	0.00003625	-0.00000988	0.00067281	0.00069918
7	-0.00122922	0.00023514	0.01600620	0.00005036	-0.00001274	0.00086684	0.00090446
8	-0.00142530	0.00024623	0.01673940	0.00006696	-0.00001575	0.00107198	0.00112320
9	-0.00161663	0.00025426	0.01729950	0.00008597	-0.00001888	0.00128460	0.00135169
10	-0.00179800	0.00026090	0.01773010	0.00010734	-0.00002210	0.00150393	0.00158917
11	-0.00196935	0.00026560	0.01806780	0.00013088	-0.00002540	0.00172747	0.00183295
12	-0.00212664	0.00026980	0.01832660	0.00015651	-0.00002873	0.00195529	0.00208307
13	-0.00227083	0.00027223	0.01851750	0.00018399	-0.00003213	0.00218535	0.00233721
14	-0.00239843	0.00027484	0.01866770	0.00021322	-0.00003554	0.00241806	0.00259574
15	-0.00251082	0.00027634	0.01879590	0.00024389	-0.00003900	0.00265195	0.00285684
16	-0.00260482	0.00027852	0.01891690	0.00027591	-0.00004245	0.00288793	0.00312139
17	-0.00268186	0.00028008	0.01904930	0.00030894	-0.00004596	0.00312492	0.00338790
18	-0.00273854	0.00028304	0.01922430	0.00034287	-0.00004946	0.00336434	0.00365775
19	-0.00277560	0.00028667	0.01949920	0.00037732	-0.00005304	0.00360595	0.00393023
20	-0.00278804	0.00029097	0.01967090	0.00041216	-0.00005663	0.00385139	0.00420692

Bending modulus calc from beam defl would be: 2377035 psi.

REWRITE FFBANK ?
** 1097. XEQ "STOP".

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TABLE 6. ASTM SBS CONFIGURATION - STRESS FUNCTION MATRIX

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Stress function matrix is:

i	j=-1	j=0	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11
0	10.833	0.000	9.833	36.205	76.000	126.733	186.351	253.126	325.574	402.392	482.406	564.520	647.673
1	10.655	0.000	9.717	35.833	75.282	125.596	184.734	250.970	322.814	398.960	478.221	559.487	641.674
2	10.326	0.000	9.388	34.784	73.248	122.375	180.153	244.864	315.020	389.301	466.501	545.480	625.116
3	9.785	0.000	8.910	33.227	70.204	117.534	173.256	235.681	303.330	374.881	449.120	524.892	601.054
4	9.219	0.000	8.344	31.351	66.496	111.599	164.776	224.385	288.972	357.234	427.964	500.010	572.237
5	8.560	0.000	7.748	29.315	62.414	105.014	155.325	211.768	272.938	337.561	404.455	472.491	540.556
6	7.960	0.000	7.147	27.220	58.158	98.087	145.330	198.387	255.911	316.674	379.532	443.392	507.177
7	7.312	0.000	6.562	25.126	53.848	91.014	135.064	184.591	238.319	295.078	353.772	413.352	472.785
8	6.745	0.000	5.995	23.062	49.550	83.903	124.685	170.591	220.425	273.081	327.522	382.750	437.784
9	6.138	0.000	5.451	21.042	45.299	76.815	114.285	156.510	202.380	250.865	300.990	351.816	402.418
10	5.613	0.000	4.925	19.068	41.105	69.777	103.908	142.410	184.270	228.536	274.301	320.689	366.836
11	5.048	0.000	4.423	17.141	36.971	62.793	93.566	128.316	166.131	206.142	247.517	289.444	331.123
12	4.562	0.000	3.937	15.252	32.881	55.844	83.237	114.210	147.953	183.684	220.648	258.102	295.310
13	4.034	0.000	3.471	13.389	28.803	48.881	72.865	100.030	129.674	161.107	193.649	226.627	259.372
14	3.580	0.000	3.018	11.522	24.677	41.816	62.338	85.652	111.166	138.283	166.399	194.911	223.216
15	3.070	0.000	2.570	9.596	20.390	34.486	51.457	70.855	92.199	114.980	138.675	162.747	186.653
16	2.592	0.000	2.092	7.480	15.714	26.585	39.865	55.249	72.368	90.801	110.095	129.778	149.363
17	1.916	0.000	1.479	4.868	10.169	17.514	26.888	38.132	50.974	65.069	80.027	95.425	110.828
18	0.772	0.000	0.335	0.923	2.631	6.002	11.217	18.221	26.806	36.675	47.472	58.811	70.288
19	-2.743	0.000	-3.118	-7.016	-9.793	-10.749	-9.707	-6.749	-2.099	3.939	11.012	18.747	26.759
20	-21.613	-16.400	-21.988	-28.833	-34.522	-38.344	-40.154	-40.057	-38.281	-35.121	-30.908	-25.991	-20.723
21	-65.788	-62.500	-66.100	-71.389	-76.351	-80.168	-82.549	-83.467	-83.039	-81.471	-79.015	-75.954	-72.579
22	-125.316	-125.000	-125.629	-127.825	-130.487	-132.837	-134.468	-135.214	-135.072	-134.138	-132.574	-130.580	-128.377
23	-187.218	-187.500	-187.468	-188.257	-189.512	-190.750	-191.643	-192.020	-191.837	-191.137	-190.022	-188.635	-187.139
24	-249.589	-250.000	-249.839	-250.026	-250.537	-251.111	-251.518	-251.621	-251.370	-250.785	-249.935	-248.923	-247.873
25	-312.159	-312.500	-312.347	-312.298	-312.442	-312.655	-312.787	-312.738	-312.463	-311.972	-311.312	-310.561	-309.809
26	-374.701	-375.000	-374.889	-374.770	-374.753	-374.790	-374.787	-374.676	-374.420	-374.024	-373.520	-372.966	-372.429
27	-437.306	-437.500	-437.431	-437.316	-437.249	-437.216	-437.165	-437.047	-436.838	-436.538	-436.170	-435.774	-435.398
28	-499.842	-500.000	-499.967	-499.884	-499.819	-499.774	-499.721	-499.628	-499.479	-499.273	-499.024	-498.759	-498.510
29	-562.428	-562.500	-562.490	-562.445	-562.404	-562.373	-562.339	-562.284	-562.196	-562.076	-561.931	-561.776	-561.631
30	-624.940	-625.000	-625.003	-624.986	-624.970	-624.958	-624.947	-624.926	-624.892	-624.844	-624.785	-624.721	-624.661
31	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500
32	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000

TABLE 6. ASTM SBS CONFIGURATION - STRESS FUNCTION MATRIX (Continued)

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Stress function matrix (continued):

i	j=9	j=10	j=11	j=12	j=13	j=14	j=15	j=16	j=17	j=18	j=19	j=20	j=21
0	482.406	564.520	647.673	730.796	812.767	892.374	968.261	1038.860	1102.310	1156.170	1196.820	1217.200	1195.820
1	478.221	559.487	641.674	723.682	804.350	882.408	956.421	1024.710	1085.260	1135.450	1171.580	1187.490	1170.640
2	466.501	545.480	625.116	704.258	781.678	856.021	925.741	989.030	1043.700	1087.030	1115.530	1124.990	1114.590
3	449.120	524.892	601.054	676.433	749.781	819.725	884.718	942.983	992.446	1030.660	1054.860	1062.490	1053.990
4	427.964	500.010	572.237	643.479	712.506	777.979	838.411	892.132	937.250	971.656	993.154	1000.000	992.280
5	404.455	472.491	540.556	607.516	672.178	733.263	789.370	838.954	880.321	911.652	931.165	937.500	930.353
6	379.532	443.392	507.177	569.793	630.102	686.894	738.863	784.597	822.583	851.253	869.114	875.000	868.302
7	353.772	413.352	472.785	531.029	587.005	639.578	687.542	729.615	764.452	790.690	807.053	812.500	806.304
8	327.522	382.750	437.784	491.638	543.297	591.707	635.759	674.295	706.125	730.062	745.003	750.000	744.253
9	300.990	351.816	402.418	451.870	499.226	543.510	583.712	618.794	647.704	669.412	682.960	687.500	682.273
10	274.301	320.689	366.836	411.879	454.942	495.129	531.526	563.207	589.249	608.765	620.931	625.000	620.244
11	247.517	289.444	331.123	371.756	410.537	446.650	479.274	507.589	530.795	548.134	558.913	562.500	558.289
12	220.648	258.102	295.310	331.539	366.055	398.120	426.999	451.976	472.364	487.530	496.910	500.000	496.286
13	193.649	226.627	259.372	291.216	321.492	349.539	374.708	396.375	413.961	426.955	434.922	437.500	434.360
14	166.399	194.911	223.216	250.708	276.787	300.864	322.368	340.765	355.578	366.407	372.950	375.000	372.388
15	138.675	162.747	186.653	209.851	231.803	251.983	269.896	285.088	297.175	305.866	310.987	312.500	310.488
16	110.095	129.778	149.363	168.363	186.297	202.699	217.138	229.234	238.685	245.299	249.027	250.000	248.528
17	80.027	95.425	110.828	125.794	139.889	152.700	163.851	173.024	179.989	184.642	187.047	187.500	186.610
18	47.472	58.811	70.288	81.498	92.044	101.554	109.698	116.212	120.926	123.808	125.020	125.000	124.583
19	11.012	18.747	26.759	34.669	42.110	48.747	54.288	58.513	61.305	62.690	62.905	62.500	62.531
20	-30.908	-25.991	-20.723	-15.450	-10.502	-6.177	-2.722	-0.316	0.966	1.200	0.675	0.000	0.300
21	-79.015	-75.954	-72.579	-69.182	-66.040	-63.401	-61.469	-60.376	-60.156	-60.700	-61.690	-62.500	-62.002
22	-132.574	-130.580	-128.377	-126.192	-124.245	-122.730	-121.805	-121.559	-121.992	-122.970	-124.170	-125.000	-124.481
23	-190.022	-188.635	-187.139	-185.709	-184.512	-183.698	-183.380	-183.615	-184.376	-185.518	-186.735	-187.500	-186.984
24	-249.935	-248.923	-247.873	-246.916	-246.180	-245.779	-245.793	-246.252	-247.114	-248.237	-249.345	-250.000	-249.594
25	-311.312	-310.561	-309.809	-309.159	-308.707	-308.536	-308.704	-309.223	-310.045	-311.039	-311.974	-312.500	-312.160
26	-373.520	-372.966	-372.429	-371.985	-371.707	-371.655	-371.868	-372.349	-373.052	-373.864	-374.599	-375.000	-374.786
27	-436.170	-435.774	-435.398	-435.099	-434.928	-434.928	-435.125	-435.518	-436.065	-436.678	-437.217	-437.500	-437.341
28	-499.024	-498.759	-498.510	-498.316	-498.212	-498.228	-498.378	-498.660	-499.042	-499.461	-499.817	-500.000	-499.942
29	-561.931	-561.776	-561.631	-561.518	-561.459	-561.472	-561.564	-561.734	-561.961	-562.204	-562.404	-562.500	-562.466
30	-624.785	-624.721	-624.661	-624.614	-624.588	-624.593	-624.631	-624.701	-624.794	-624.891	-624.967	-625.000	-625.030
31	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500	-687.500
32	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000	-750.000

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TABLE 7. ASTM SBS CONFIGURATION - AXIAL STRESSES (ksi)

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Axial stresses (ksi) are:

I	j=0	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11	j=12
0	132.26	105.85	85.91	69.99	56.87	45.81	36.31	27.97	20.45	13.44	6.65	-0.20	-7.37
1	130.38	104.95	85.33	69.54	56.47	45.42	35.90	27.53	19.94	12.83	5.90	-1.14	-8.58
2	126.17	102.45	83.64	68.24	55.36	44.38	34.85	26.40	18.68	11.38	4.21	-3.16	-11.02
3	119.64	98.61	81.02	66.26	53.71	42.90	33.43	24.98	17.20	9.81	2.50	-5.01	-13.00
4	112.41	93.84	77.68	63.74	51.67	41.16	31.87	23.52	15.79	8.43	1.15	-6.30	-14.18
5	104.37	88.44	73.80	60.80	49.35	39.25	30.25	22.10	14.53	7.31	0.18	-7.08	-14.70
6	96.69	82.72	69.54	57.55	46.80	37.21	28.59	20.73	13.41	6.41	-0.48	-7.48	-14.76
7	88.80	76.81	65.01	54.04	44.06	35.05	26.89	19.39	12.38	5.67	-0.94	-7.61	-14.51
8	81.54	70.86	60.30	50.33	41.16	32.79	25.14	18.07	11.42	5.04	-1.24	-7.56	-14.04
9	74.17	64.90	55.46	46.46	38.11	30.42	23.34	16.74	10.49	4.49	-1.43	-7.36	-13.42
10	67.45	58.99	50.53	42.46	34.94	27.97	21.49	15.40	9.60	3.99	-1.54	-7.07	-12.68
11	60.61	53.09	45.51	38.35	31.68	25.46	19.61	14.06	8.72	3.54	-1.58	-6.70	-11.85
12	54.40	47.22	40.40	34.14	28.35	22.91	17.72	12.73	7.88	3.13	-1.57	-6.26	-10.97
13	48.03	41.26	35.17	29.85	24.99	20.36	15.86	11.45	7.10	2.79	-1.49	-5.76	-10.03
14	42.23	35.11	29.76	25.50	21.65	17.87	14.08	10.25	6.40	2.54	-1.33	-5.20	-9.04
15	36.09	28.52	24.12	21.13	18.40	15.53	12.45	9.21	5.84	2.41	-1.06	-4.53	-7.98
16	29.97	21.10	18.22	16.88	15.41	13.47	11.10	8.41	5.51	2.48	-0.62	-3.74	-6.83
17	21.73	12.23	12.24	13.07	12.99	11.96	10.23	8.03	5.52	2.82	0.03	-2.79	-5.57
18	7.09	1.62	7.17	10.64	11.80	11.44	10.12	8.21	5.94	3.47	0.89	-1.71	-4.25
19	-37.52	-4.99	7.17	11.65	12.79	12.26	10.83	8.88	6.63	4.23	1.78	-0.66	-3.00
20	-69.12	-8.05	7.40	11.95	12.87	12.21	10.75	8.86	6.74	4.51	2.25	0.03	-2.08
21	-44.08	-10.81	2.10	7.32	9.19	9.37	8.61	7.30	5.68	3.88	2.01	0.14	-1.63
22	-6.05	-10.03	-2.97	1.99	4.61	5.66	5.69	5.07	4.03	2.75	1.34	-0.12	-1.52
23	2.01	-5.26	-2.98	0.10	2.21	3.30	3.59	3.31	2.65	1.74	0.69	-0.42	-1.49
24	3.66	-2.23	-2.07	-0.40	1.06	1.95	2.26	2.14	1.70	1.04	0.25	-0.60	-1.42
25	3.16	-0.67	-1.24	-0.44	0.51	1.17	1.44	1.39	1.08	0.59	-0.00	-0.65	-1.27
26	2.62	0.05	-0.66	-0.34	0.25	0.70	0.92	0.90	0.69	0.33	-0.11	-0.60	-1.06
27	1.68	0.29	-0.30	-0.22	0.12	0.42	0.59	0.58	0.44	0.18	-0.14	-0.49	-0.82
28	1.22	0.32	-0.12	-0.13	0.05	0.25	0.36	0.37	0.27	0.11	-0.11	-0.35	-0.58
29	0.52	0.23	-0.03	-0.07	0.02	0.14	0.20	0.21	0.16	0.06	-0.07	-0.21	-0.34
30	0.36	0.13	-0.00	-0.03	0.00	0.06	0.08	0.09	0.07	0.03	-0.02	-0.08	-0.14
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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TABLE 7. ASTM SBS CONFIGURATION - AXIAL STRESSES (ksi) (Continued)

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Axial stresses (ksi) (continued):

i	j=13	j=14	j=15	j=16	j=17	j=18	j=19	j=20
0	-15.13	-23.80	-33.80	-45.82	-61.36	-84.52	-129.79	-267.17
1	-16.71	-25.89	-36.59	-49.57	-66.28	-90.01	-129.38	-209.67
2	-19.70	-29.58	-41.16	-55.13	-72.58	-94.95	-121.80	-127.15
3	-21.79	-31.68	-43.06	-56.34	-71.95	-89.72	-106.05	-103.27
4	-22.75	-32.26	-42.96	-55.05	-68.55	-82.62	-93.77	-93.22
5	-22.90	-31.86	-41.74	-52.60	-64.22	-75.64	-84.34	-86.28
6	-22.51	-30.86	-39.90	-49.59	-59.63	-69.18	-76.64	-80.54
7	-21.78	-29.50	-37.70	-46.32	-55.03	-63.20	-69.87	-74.50
8	-20.80	-27.89	-35.30	-42.93	-50.51	-57.58	-63.64	-68.75
9	-19.66	-26.12	-32.77	-39.50	-46.09	-52.22	-57.66	-62.50
10	-18.40	-24.25	-30.19	-36.08	-41.77	-47.04	-51.82	-56.47
11	-17.07	-22.33	-27.58	-32.70	-37.55	-41.99	-46.03	-49.91
12	-15.69	-20.38	-24.98	-29.37	-33.42	-37.03	-40.26	-43.54
13	-14.27	-18.42	-22.41	-26.11	-29.40	-32.17	-34.49	-36.60
14	-12.82	-16.47	-19.88	-22.94	-25.49	-27.43	-28.76	-29.83
15	-11.33	-14.51	-17.41	-19.87	-21.74	-22.84	-23.10	-22.56
16	-9.80	-12.57	-15.00	-16.93	-18.16	-18.47	-17.64	-15.64
17	-8.22	-10.63	-12.66	-14.13	-14.80	-14.38	-12.49	-8.60
18	-6.63	-8.74	-10.44	-11.52	-11.72	-10.69	-7.88	-2.54
19	-5.15	-7.01	-8.42	-9.18	-9.00	-7.49	-3.97	2.79
20	-3.98	-5.58	-6.71	-7.19	-6.71	-4.86	-0.95	6.24
21	-3.22	-4.52	-5.37	-5.59	-4.88	-2.86	1.15	8.37
22	-2.77	-3.77	-4.35	-4.34	-3.49	-1.42	2.37	8.63
23	-2.45	-3.18	-3.54	-3.37	-2.44	-0.48	2.89	8.19
24	-2.14	-2.65	-2.85	-2.58	-1.67	0.09	2.90	6.79
25	-1.80	-2.16	-2.25	-1.94	-1.10	0.39	2.61	5.54
26	-1.45	-1.70	-1.71	-1.42	-0.70	0.49	2.14	3.93
27	-1.10	-1.26	-1.25	-0.99	-0.42	0.48	1.63	2.83
28	-0.76	-0.87	-0.84	-0.64	-0.23	0.39	1.12	1.54
29	-0.45	-0.51	-0.50	-0.36	-0.10	0.27	0.67	0.83
30	-0.19	-0.21	-0.21	-0.15	-0.03	0.14	0.28	0.02
31	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00

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TABLE 8. ASTM SBS CONFIGURATION - TRANSVERSE STRESSES (ksi)

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Transverse stresses (ksi) are:

i	j=0	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11	j=12
0	0.00	-0.37	-1.19	-2.30	-3.64	-5.17	-6.90	-8.83	-10.98	-13.39	-16.11	-19.20	-22.77
1	0.00	-0.34	-1.08	-2.10	-3.33	-4.74	-6.32	-8.06	-9.96	-12.06	-14.36	-16.89	-19.70
2	0.00	-0.24	-0.81	-1.62	-2.59	-3.70	-4.92	-6.23	-7.62	-9.06	-10.53	-12.01	-13.44
3	0.00	-0.14	-0.51	-1.06	-1.75	-2.53	-3.38	-4.27	-5.16	-6.04	-6.87	-7.61	-8.21
4	0.00	-0.05	-0.26	-0.60	-1.04	-1.56	-2.11	-2.68	-3.24	-3.76	-4.22	-4.58	-4.82
5	0.00	-0.01	-0.09	-0.28	-0.55	-0.87	-1.22	-1.59	-1.94	-2.26	-2.53	-2.72	-2.81
6	0.00	0.02	0.00	-0.08	-0.24	-0.43	-0.66	-0.90	-1.13	-1.34	-1.51	-1.62	-1.67
7	0.00	0.03	0.05	0.02	-0.06	-0.18	-0.33	-0.49	-0.64	-0.78	-0.90	-0.97	-1.00
8	0.00	0.04	0.07	0.07	0.04	-0.03	-0.13	-0.24	-0.35	-0.45	-0.53	-0.58	-0.60
9	0.00	0.03	0.07	0.09	0.08	0.04	-0.03	-0.10	-0.18	-0.25	-0.31	-0.35	-0.36
10	0.00	0.04	0.08	0.09	0.09	0.06	0.01	-0.05	-0.10	-0.15	-0.19	-0.21	-0.21
11	0.00	0.03	0.06	0.07	0.05	0.02	-0.02	-0.06	-0.10	-0.14	-0.16	-0.16	-0.15
12	0.00	0.03	0.04	0.02	-0.02	-0.07	-0.12	-0.16	-0.19	-0.21	-0.21	-0.20	-0.17
13	0.00	0.02	-0.01	-0.08	-0.16	-0.25	-0.32	-0.37	-0.39	-0.40	-0.38	-0.35	-0.30
14	0.00	0.01	-0.10	-0.26	-0.42	-0.57	-0.67	-0.74	-0.76	-0.76	-0.72	-0.65	-0.56
15	0.00	-0.05	-0.30	-0.62	-0.91	-1.14	-1.29	-1.38	-1.40	-1.37	-1.29	-1.17	-1.01
16	0.00	-0.22	-0.79	-1.39	-1.87	-2.21	-2.42	-2.50	-2.48	-2.38	-2.21	-1.99	-1.73
17	0.00	-0.85	-2.13	-3.19	-3.90	-4.31	-4.47	-4.44	-4.26	-3.98	-3.62	-3.21	-2.76
18	0.00	-3.70	-6.39	-7.82	-8.38	-8.41	-8.09	-7.58	-6.95	-6.25	-5.52	-4.78	-4.05
19	-26.24	-24.67	-22.21	-19.69	-17.35	-15.24	-13.34	-11.64	-10.12	-8.74	-7.48	-6.33	-5.27
20	-47.52	-40.39	-33.18	-27.36	-22.77	-19.12	-16.16	-13.72	-11.66	-9.90	-8.36	-7.00	-5.78
21	-26.24	-24.67	-22.21	-19.69	-17.35	-15.24	-13.34	-11.64	-10.11	-8.72	-7.46	-6.31	-5.24
22	0.00	-3.70	-6.39	-7.82	-8.39	-8.41	-8.09	-7.57	-6.93	-6.22	-5.49	-4.74	-4.01
23	-0.00	-0.85	-2.14	-3.20	-3.92	-4.32	-4.47	-4.43	-4.24	-3.94	-3.57	-3.15	-2.70
24	0.00	-0.22	-0.80	-1.41	-1.89	-2.23	-2.43	-2.50	-2.46	-2.34	-2.16	-1.92	-1.66
25	-0.00	-0.06	-0.32	-0.65	-0.95	-1.17	-1.31	-1.38	-1.38	-1.33	-1.23	-1.09	-0.93
26	0.00	0.00	-0.12	-0.29	-0.47	-0.60	-0.69	-0.74	-0.74	-0.71	-0.64	-0.56	-0.46
27	0.00	0.01	-0.03	-0.12	-0.21	-0.29	-0.34	-0.36	-0.35	-0.33	-0.28	-0.23	-0.17
28	0.00	0.02	0.01	-0.02	-0.06	-0.10	-0.12	-0.12	-0.11	-0.08	-0.05	-0.01	0.03
29	0.00	0.02	0.03	0.03	0.02	0.02	0.02	0.03	0.06	0.08	0.11	0.15	0.17
30	0.00	0.02	0.04	0.06	0.07	0.09	0.11	0.14	0.18	0.22	0.27	0.31	0.33
31	0.00	-0.00	0.02	0.05	0.07	0.09	0.12	0.17	0.25	0.34	0.45	0.54	0.62

TABLE 8. ASTM SBS CONFIGURATION - TRANSVERSE STRESSES (ksi) (Continued)

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Transverse stresses (ksi) (continued):

i	j=13	j=14	j=15	j=16	j=17	j=18	j=19	j=20
0	-26.94	-31.89	-37.89	-45.28	-54.56	-66.29	-80.77	-95.05
1	-22.81	-26.27	-30.14	-34.46	-39.22	-44.33	-49.30	-52.48
2	-14.76	-15.85	-16.55	-16.58	-15.51	-12.72	-7.38	-0.00
3	-8.60	-8.72	-8.45	-7.69	-6.30	-4.23	-1.68	0.00
4	-4.89	-4.75	-4.38	-3.72	-2.77	-1.59	-0.44	-0.00
5	-2.80	-2.64	-2.34	-1.89	-1.29	-0.63	-0.10	0.00
6	-1.64	-1.52	-1.30	-1.00	-0.63	-0.26	-0.01	0.00
7	-0.98	-0.89	-0.74	-0.54	-0.31	-0.10	0.01	0.00
8	-0.58	-0.52	-0.42	-0.29	-0.15	-0.04	0.01	0.00
9	-0.34	-0.29	-0.22	-0.14	-0.05	0.01	0.02	0.00
10	-0.19	-0.16	-0.10	-0.05	0.00	0.03	0.02	0.00
11	-0.12	-0.08	-0.04	0.01	0.04	0.04	0.03	-0.00
12	-0.13	-0.08	-0.03	0.02	0.05	0.05	0.02	0.00
13	-0.23	-0.15	-0.08	-0.01	0.03	0.04	0.03	0.00
14	-0.45	-0.33	-0.21	-0.11	-0.03	0.01	0.01	0.00
15	-0.83	-0.65	-0.46	-0.28	-0.14	-0.04	0.00	0.00
16	-1.44	-1.14	-0.85	-0.57	-0.33	-0.14	-0.03	0.00
17	-2.30	-1.84	-1.38	-0.96	-0.59	-0.28	-0.07	-0.00
18	-3.34	-2.66	-2.01	-1.42	-0.89	-0.45	-0.14	-0.00
19	-4.29	-3.39	-2.56	-1.81	-1.15	-0.60	-0.19	0.00
20	-4.68	-3.68	-2.78	-1.97	-1.25	-0.66	-0.21	0.00
21	-4.27	-3.37	-2.54	-1.80	-1.14	-0.59	-0.18	-0.00
22	-3.30	-2.62	-1.98	-1.40	-0.88	-0.45	-0.14	0.00
23	-2.24	-1.78	-1.34	-0.93	-0.57	-0.27	-0.07	-0.00
24	-1.37	-1.08	-0.80	-0.53	-0.31	-0.13	-0.03	0.00
25	-0.76	-0.58	-0.41	-0.25	-0.12	-0.04	0.00	-0.00
26	-0.35	-0.25	-0.15	-0.07	-0.01	0.02	0.01	0.00
27	-0.10	-0.04	0.01	0.04	0.06	0.05	0.03	0.00
28	0.06	0.09	0.11	0.11	0.09	0.06	0.02	0.00
29	0.19	0.20	0.19	0.17	0.14	0.09	0.04	0.00
30	0.35	0.34	0.32	0.27	0.20	0.13	0.05	0.00
31	0.66	0.65	0.59	0.48	0.33	0.17	0.05	0.00

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TABLE 9. ASTM SBS CONFIGURATION - SHEAR STRESSES (ksi)

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Shear stresses (ksi) are:

i	j=0	j=1	j=2	j=3	j=4	j=5	j=6	j=7	j=8	j=9	j=10	j=11	j=12
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	-0.05	1.14	1.85	2.35	2.76	3.12	3.48	3.86	4.28	4.76	5.32	6.00	6.83
2	-0.05	2.09	3.42	4.36	5.12	5.78	6.41	7.03	7.69	8.41	9.22	10.12	11.16
3	-0.05	2.75	4.57	5.88	6.90	7.76	8.54	9.27	9.99	10.72	11.47	12.25	13.03
4	-0.05	3.13	5.30	6.89	8.11	9.11	9.97	10.73	11.42	12.06	12.67	13.21	13.68
5	-0.05	3.31	5.71	7.50	8.89	9.99	10.89	11.65	12.30	12.85	13.30	13.65	13.88
6	-0.05	3.35	5.90	7.85	9.36	10.54	11.49	12.24	12.85	13.33	13.67	13.88	13.92
7	-0.05	3.33	5.96	8.02	9.63	10.89	11.87	12.64	13.22	13.64	13.91	14.01	13.93
8	-0.05	3.27	5.95	8.09	9.78	11.11	12.13	12.91	13.47	13.86	14.07	14.10	13.93
9	-0.05	3.20	5.90	8.11	9.87	11.24	12.30	13.09	13.65	14.01	14.18	14.16	13.93
10	-0.05	3.12	5.84	8.10	9.91	11.34	12.42	13.22	13.78	14.12	14.26	14.19	13.91
11	-0.05	3.05	5.79	8.09	9.96	11.41	12.52	13.32	13.87	14.19	14.30	14.20	13.89
12	-0.05	3.00	5.77	8.13	10.03	11.50	12.61	13.40	13.93	14.23	14.31	14.18	13.83
13	-0.05	2.98	5.83	8.24	10.16	11.62	12.71	13.48	13.97	14.23	14.28	14.11	13.74
14	-0.05	3.04	6.01	8.48	10.40	11.82	12.85	13.56	14.00	14.20	14.20	13.99	13.58
15	-0.05	3.23	6.43	8.95	10.81	12.14	13.06	13.66	14.00	14.12	14.04	13.77	13.31
16	-0.05	3.78	7.30	9.80	11.48	12.60	13.32	13.75	13.94	13.93	13.74	13.39	12.87
17	-0.05	5.25	9.06	11.22	12.45	13.16	13.53	13.68	13.65	13.47	13.16	12.72	12.14
18	-0.05	9.51	12.29	13.10	13.31	13.29	13.18	13.00	12.75	12.44	12.04	11.56	10.97
19	-0.05	10.68	11.86	11.67	11.37	11.15	10.97	10.81	10.63	10.40	10.10	9.72	9.23
20	-0.05	1.50	2.86	4.04	5.03	5.84	6.48	6.95	7.27	7.43	7.45	7.32	7.05
21	-0.05	-7.69	-6.14	-3.60	-1.32	0.53	1.98	3.09	3.90	4.46	4.79	4.92	4.87
22	-0.05	-6.51	-6.57	-5.03	-3.25	-1.62	-0.24	0.89	1.77	2.41	2.84	3.08	3.13
23	-0.05	-2.24	-3.33	-3.14	-2.40	-1.49	-0.60	0.19	0.85	1.36	1.71	1.90	1.95
24	-0.05	-0.77	-1.56	-1.71	-1.43	-0.95	-0.41	0.09	0.53	0.87	1.10	1.22	1.22
25	-0.05	-0.21	-0.67	-0.85	-0.76	-0.50	-0.18	0.15	0.43	0.64	0.78	0.82	0.78
26	-0.05	0.01	-0.22	-0.37	-0.34	-0.20	-0.00	0.21	0.39	0.52	0.58	0.58	0.51
27	-0.05	0.09	-0.01	-0.10	-0.11	-0.03	0.10	0.24	0.36	0.43	0.46	0.43	0.34
28	-0.05	0.10	0.08	0.02	0.02	0.06	0.15	0.24	0.32	0.37	0.38	0.33	0.24
29	-0.05	0.08	0.09	0.07	0.06	0.09	0.15	0.22	0.28	0.31	0.31	0.27	0.18
30	-0.05	0.04	0.07	0.06	0.05	0.07	0.11	0.17	0.21	0.24	0.24	0.21	0.14
31	-0.05	0.01	0.03	0.02	0.02	0.03	0.04	0.07	0.09	0.10	0.10	0.09	0.06

TABLE 9. ASTM SBS CONFIGURATION - SHEAR STRESSES (ksi) (Continued)

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Shear stresses (ksi) (continued):

I	j=13	j=14	j=15	j=16	j=17	j=18	j=19	j=20
0	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	7.85	9.14	10.79	12.87	15.44	18.15	18.45	-0.05
2	12.35	13.71	15.24	16.89	18.45	19.12	16.17	-0.05
3	13.81	14.53	15.09	15.30	14.79	12.74	7.69	-0.05
4	14.04	14.20	14.05	13.42	11.99	9.26	4.79	-0.05
5	13.92	13.72	13.16	12.09	10.29	7.50	3.68	-0.05
6	13.76	13.32	12.52	11.23	9.30	6.59	3.23	-0.05
7	13.63	13.04	12.09	10.68	8.71	6.12	3.05	-0.05
8	13.53	12.84	11.80	10.33	8.37	5.88	2.98	-0.05
9	13.46	12.70	11.61	10.11	8.17	5.76	2.96	-0.05
10	13.40	12.60	11.48	9.98	8.06	5.71	2.98	-0.05
11	13.34	12.51	11.38	9.89	8.00	5.71	3.01	-0.05
12	13.26	12.42	11.28	9.81	7.97	5.73	3.06	-0.05
13	13.14	12.29	11.16	9.72	7.93	5.74	3.10	-0.05
14	12.95	12.10	10.98	9.58	7.84	5.72	3.13	-0.05
15	12.66	11.79	10.69	9.33	7.66	5.62	3.11	-0.05
16	12.18	11.31	10.23	8.91	7.33	5.40	3.02	-0.05
17	11.42	10.55	9.50	8.26	6.78	5.00	2.81	-0.05
18	10.26	9.43	8.45	7.30	5.95	4.37	2.44	-0.05
19	8.63	7.90	7.04	6.03	4.86	3.51	1.91	-0.05
20	6.64	6.08	5.39	4.56	3.60	2.51	1.29	-0.05
21	4.65	4.27	3.75	3.10	2.34	1.51	0.66	-0.05
22	3.02	2.75	2.35	1.85	1.26	0.66	0.15	-0.05
23	1.86	1.64	1.32	0.91	0.46	0.04	-0.21	-0.05
24	1.11	0.90	0.62	0.28	-0.07	-0.34	-0.42	-0.05
25	0.64	0.44	0.18	-0.11	-0.38	-0.55	-0.50	-0.05
26	0.36	0.16	-0.08	-0.32	-0.53	-0.62	-0.51	-0.05
27	0.19	0.00	-0.21	-0.42	-0.57	-0.62	-0.48	-0.05
28	0.10	-0.07	-0.26	-0.43	-0.55	-0.57	-0.42	-0.05
29	0.05	-0.10	-0.26	-0.40	-0.49	-0.48	-0.34	-0.05
30	0.04	-0.08	-0.21	-0.32	-0.38	-0.35	-0.24	-0.05
31	0.02	-0.03	-0.09	-0.13	-0.15	-0.14	-0.09	-0.05

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TABLE 10. ASTM SBS CONFIGURATION - DEFORMATIONS

ASTM SBS CONFIGURATION

Exx= 10600000. Eyy= 5050000. Ezz= 1970000. Gxz= 760000. Vxz= .25 Vxy= .47 Vzy= .15 821213
PLANE STRAIN: Kx= .136751 , Kz= .774934 Sh= 2500 P= 5000
L= 1 h= .25 Lc= .5 Lp= .031 aa= .025 bb= .0125

Deformations are:

Sta	(du/dz)fx	(du/dz)fz	gamma	(wb)fx-in.	(wb)fz-in.	ws-in.	wt-in.
0	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000	0.00000000
1	-0.00115544	0.00010359	0.00700298	0.00001445	-0.00000128	0.00008726	0.00010042
2	-0.00234916	0.00018063	0.01212500	0.00005809	-0.00000496	0.00033447	0.00038761
3	-0.00358552	0.00022119	0.01509660	0.00013226	-0.00001001	0.00067559	0.00079784
4	-0.00482369	0.00024579	0.01666550	0.00023738	-0.00001588	0.00107762	0.00129911
5	-0.00604967	0.00025571	0.01750360	0.00037334	-0.00002218	0.00150277	0.00185394
6	-0.00723485	0.00026487	0.01798770	0.00053953	-0.00002866	0.00194985	0.00246071
7	-0.00837987	0.00026727	0.01829690	0.00073475	-0.00003537	0.00240070	0.00310009
8	-0.00946509	0.00027256	0.01850990	0.00095802	-0.00004205	0.00286389	0.00377986
9	-0.01049680	0.00027265	0.01865980	0.00120756	-0.00004895	0.00332568	0.00448428
10	-0.01145820	0.00027628	0.01876000	0.00148227	-0.00005571	0.00379647	0.00522303
11	-0.01235810	0.00027498	0.01881510	0.00177996	-0.00006272	0.00426330	0.00598053
12	-0.01318200	0.00027725	0.01882450	0.00209955	-0.00006949	0.00473684	0.00676689
13	-0.01394190	0.00027453	0.01878360	0.00243853	-0.00007655	0.00520410	0.00756608
14	-0.01462610	0.00027514	0.01867860	0.00279601	-0.00008325	0.00567548	0.00838825
15	-0.01524910	0.00027004	0.01847320	0.00316932	-0.00009025	0.00613719	0.00921626
16	-0.01580250	0.00026655	0.01808150	0.00355789	-0.00009676	0.00659759	0.01005872
17	-0.01630600	0.00025350	0.01731700	0.00395903	-0.00010350	0.00703816	0.01089369
18	-0.01675920	0.00023448	0.01584570	0.00437277	-0.00010939	0.00745755	0.01172093
19	-0.01718890	0.00019507	0.01329560	0.00479680	-0.00011506	0.00782145	0.01250319
20	-0.01758560	0.00014444	0.00980150	0.00523194	-0.00011905	0.00811446	0.01322735
21	-0.01793960	0.00008967	0.00630302	0.00567572	-0.00012224	0.00831149	0.01386497
22	-0.01821720	0.00005414	0.00373995	0.00612829	-0.00012369	0.00843740	0.01444200
23	-0.01843340	0.00003073	0.00224706	0.00658607	-0.00012505	0.00850740	0.01496842
24	-0.01859200	0.00002129	0.00145236	0.00704947	-0.00012534	0.00855557	0.01547970
25	-0.01871730	0.00001314	0.00102210	0.00751539	-0.00012613	0.00858305	0.01597232
26	-0.01880690	0.00001142	0.00076943	0.00798504	-0.00012605	0.00860815	0.01646714
27	-0.01887790	0.00000709	0.00060778	0.00845558	-0.00012668	0.00862228	0.01695119
28	-0.01892380	0.00000743	0.00049728	0.00892872	-0.00012645	0.00863897	0.01744124
29	-0.01895770	0.00000421	0.00041067	0.00940167	-0.00012702	0.00864734	0.01792199
30	-0.01897120	0.00000480	0.00031558	0.00987644	-0.00012669	0.00865943	0.01840917
31	-0.01897860	0.00000032	0.00013055	0.01035010	-0.00012722	0.00866237	0.01888532

Bending modulus calc from beam defl would be: 6048073 psi.

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15. Supplementary Notes

a) Langley Technical Monitor: H. A. Leybold

16. Abstract

A program is being conducted to identify and resolve technical problems associated with fuel containment and damage tolerance of composite material wings for transport aircraft. The major tasks within the program are the following: a) the preliminary design of damage tolerant wing surface using composite materials, b) the evaluation of fuel sealing and lightning protection methods for a composite material wing, and c) an experimental investigation of the damage tolerant characteristics of toughened resin graphite/epoxy materials.

This report presents the test results for work on Phase I of the contract. Included within the report is a description of the test techniques and the test data which were obtained.

17. Key Words (Suggested by Author(s))	18. Distribution Statement
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